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MODERN APPLICATIONS OF PHOTOGRAPHY.*

BY

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THE word "photography" means to sketch or draw by light; thus a photograph is a record of the chemical activity of light upon a sensitive surface. A photographic emulsion, which is the light-sensitive medium, is prepared by precipitating silver bromide, silver iodide or silver chloride in gelatine, either separately or in combination, according to the character of the emulsion desired. The precipitate thus obtained is exceedingly fine and is held in suspension in the gelatine solution forming an emulsion. This emulsion is coated upon glass, celluloid or paper, according to the purpose for which it is intended. Negative emulsions, such as are used in the camera, are made with silver bromide, and in some cases a small proportion of silver iodide. They are extremely sensitive to light and form the basis of all our photographic operations. When a plate or film is exposed in the camera to the image formed by a lens, a change takes place in the silver halide under the action of light, and the change is proportionate to the intensity of the light at any part of the image; in other words, a developable or latent image is formed. It is not proposed to discuss the theories of the latent image. Scientists have been speculating upon its composition for years,

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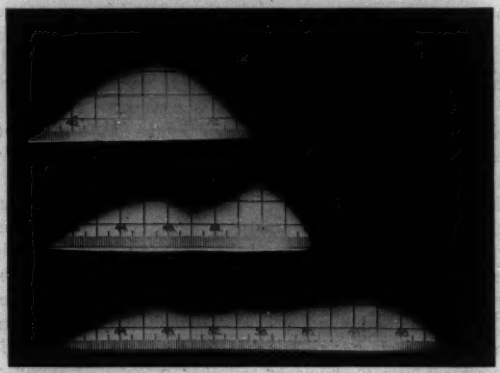
and at the present time no one really knows of what it is composed or how it is formed. It is sufficient to know that under the action of light a definite change takes place in the silver halide, rendering it susceptible to development, with consequent reduction to metallic silver which forms the finished photographic image. The image so obtained is a negative, that is to say it is the reverse of the original—white is rendered as black, and black as white. The negative, when dry, is printed upon a photographic paper which is usually coated with a silver chloride emulsion. The negative is brought into intimate contact with the silver chloride paper and exposed to a light source. The paper is affected in proportion to the opacities of the negative and upon development yields a print in monochrome, which is a correct representation of the object photographed.

The most common uses of photography are in portraiture and pictorial representation. It is not necessary to discuss these applications of photography. The work of the professional and amateur photographer is familiar to everyone. It will be as well at this point to explain one of the peculiarities of ordinary photography. The eye is affected most by yellow, orange and green rays, and to some extent by red rays, which therefore appear bright to us; the ordinary photographic plate is practically insensitive to these rays, so that they appear dark in photographs. Blue and violet, on the other hand, have a very small effect upon the eye and appear dark to us, but they most strongly affect the photographic plate and therefore appear as white in the photograph. At that portion of the plate where the blue part of the image falls, photographic action takes place and density in the negative results and is rendered as white on the print; at that part of the plate where the yellow, orange or red image falls little or no photographic action occurs, because the plate is not sensitive to these rays. This results in practically clear glass, which, when printed, yields a dark gray or black, and a photograph under these circumstances is contrary to the visual effect. Had it not been found possible to sensitize a photographic emulsion for colors other than blue and blue-violet, photography would have found but little application in the sciences and arts because of its untruthful rendering. Happily, however, methods have been discovered of rendering the photographic emulsion sensitive to practically the whole spectrum. This subject naturally leads

us to a consideration of color-correct photography; that is, the possibility of rendering in monochrome color luminosities as seen by the eye. These points can be best explained by illustration. Fig. 1 shows a series of photographs of the spectrum upon various photographic emulsions. These were made in a spectrograph having in front of the slit a graduated black glass wedge which grades the exposure across the width of the spectrum band and so automatically plots the curve of color-sensitiveness. Curve I was made upon an ordinary or non-color-sensitive emulsion. The

FIG. 1.

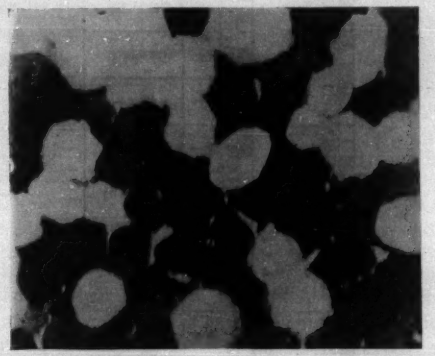


maximum sensitiveness is in the blue and there is practically no action beyond blue-green. Such an emulsion, as previously described, will not render color luminosities truthfully. Curve II was made upon an orthochromatic plate. Emulsions are rendered orthochromatic by the addition of a dye to the emulsion, usually erythrosine. The silver bromide grain is dyed and sensitiveness is conferred in the region of the color absorbed by the dye; this results in a secondary maximum in the yellow-green. Such an emulsion, when used with a yellow screen, will approximately render color luminosities as seen by the eye. Curve III shows a photograph of the spectrum made upon a panchromatic emulsion. Panchromatic means sensitive to all colors of the

spectrum, and this quality is obtained by bathing a silver bromide emulsion in various dyes, usually of the isocyanine group; the dyes most commonly used being homocol, pinaverdol and pinacyanol. One of the chief uses of panchromatic plates is in the practice of the so-called commercial photography and embraces such subjects as the reproduction of paintings, stained glass, tapestries, various-colored woods, in fact, any subjects which are multi-colored and where it is necessary to render correctly color luminosities in monochrome. When working with panchromatic plates, it is possible by the use of compensating or contrast color filters to subdue or emphasize any particular color; that is to say, we may at will increase or decrease detail in any particular color region. A very important use of panchromatic emulsions is in three-color photography. This process is in general use for the illustration of our books and magazines, and is dependent upon the use of panchromatic plates in conjunction with certain selective color filters. Three selective negatives are made of the subject through a red, green and blue-violet filter respectively. From the selective negatives so obtained, printing plates are prepared which are inked up with inks of a color complementary to the taking filters. The color images are printed one on top of the other in perfect registration, and the resulting composite print is a fairly accurate reproduction of the original colored object. The practice of tri-color photography calls for a highly specialized knowledge and a great deal of manipulative skill, and is confined to a few specialists who are thoroughly equipped for the work. There is, however, another process of direct-color photography known as the screen-plate method which may be practiced very successfully by the ordinary photographic worker. There are several screen plates upon the market, but up to the present time the most perfect is the autochrome process of Lumierè. Three batches of potato starch grains are dyed red, green and blue-violet respectively, and after dyeing, the starch cells are intimately mixed in the proportion of four green to three red and two blue. By an ingenious coating machine the mixed grains are spread on glass plates, flattened out by rollers to fill in the interstices and then varnished. Upon this color screen a panchromatic emulsion is coated. Fig. 2 shows the structure of the color screen. This illustration is a photomicrograph magnified 800 diameters. It will be seen that the whole of the plate

is covered with a large number of microscopic tri-color screens. When such a plate is exposed in the camera with the glass side turned towards the lens, so that the microscopic screens intercept the image before it falls upon the panchromatic emulsion, we obtain a result shown diagrammatically by Fig. 3.[1] A red object absorbs green and blue and emits only red rays. These pass through the red elements of the screen and act on the silver bromide emulsion behind them. The film at that point will be blackened during the course of development; the excess red rays will be absorbed by the blue and green elements of the screen, and

FIG. 2.

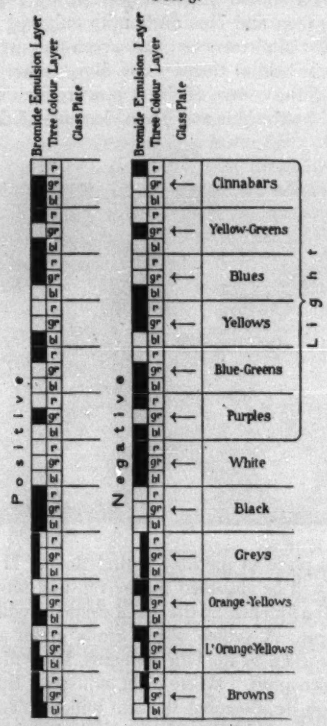


no change takes place in the film behind them. If the object is green, the rays will be absorbed by the red and blue elements of the screen, and the film behind the green elements will be blackened upon development. A yellow object emits green and red rays; these will be absorbed by the blue elements, but will pass through the red and green ones. White light will pass through all the screens, and upon development the film will be blackened behind all three elements. A black object reflects but little light, and the developed negative will not show a deposit under any of the screens. It is obvious that if this process is stopped at the negative stage the results, when viewed by transmitted light,

[1] From "Photography in Colors," by Dr. Lindsay Johnson.

will be in colors complementary to the original. The negative is, however, reversed by a chemical process which dissolves away the whole of the blackened silver deposit; the plate is then exposed

FIG. 3.



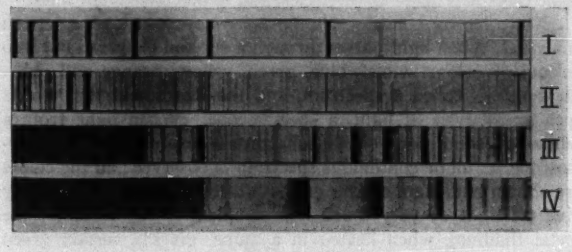
to light and redeveloped, when the whole of the silver bromide particles, which had not been acted on originally, will now be reduced to blackened silver and a positive image will result, revealing the true colors of the original, because where, for instance, the red, green and blue images fell, the red, green and

blue grains are free from silver deposit, and by transmitted light we shall see these colors. Mixed colors are formed by partial backing up of one or more of the screen elements, and the plate viewed as a whole is a faithful reproduction of the original colors. Autochromes can be made in an ordinary camera. The only additional apparatus necessary is a yellow-taking filter, which is placed in front of the lens during exposure to cut down the activity of the blue rays. The starch grains are between .01 and .02 mm., or about the size of a white blood-corpuscle, so that to the eye the plate is practically structureless. The various other screen plates to be obtained are all based upon the same principle as the autochrome, that is, the whole of the plate is covered with microscopic tri-color screens—the only difference being that in some cases the composite color screen is of geometric design; in some cases it is made up of circles, and in others straight lines.

Now, let us consider photography as applied to spectrum analysis. When light passes through a slit and is spread out into a band of colors—violet, blue, green, yellow, orange and red—the result is called a spectrum, and the instrument that effects such an analysis of light, a spectroscope. When light from a white-hot, solid, non-volatile substance is examined with a spectroscope, a full or continuous spectrum is observed; all the colors are shown and there are no gaps. Volatile substances generally give off light of very much less complexity; for instance, the metal thallium, when heated in a flame, gives a certain green light that cannot be decomposed, and thallium is the only substance which produces light of exactly this character, so that when such light is observed we know that thallium is present to produce it. Sodium gives a particular yellow light which is not obtained with any other substance. Most substances, when their vapors are made to glow, give very complex lights, and their spectra show a number of fine lines, and from the number and position of these lines we can with certainty tell what substance gives rise to them, for no two substances, when their vapors are luminous, have ever been found to give the same spectrum. If spectra are observed by the eye, it is obvious that we must be limited to light that affects the eye—that is, to visible light—but we can photograph not only all visible light, but a great deal more that extends in the spectrum beyond the violet at one end and the red at the other. Photography has, therefore, provided

us with a means of obtaining a permanent record that can be measured at leisure and has extended vastly the range of spectroscopy, bringing out facts that never could have been known without its aid. Such photographs render with wonderful accuracy an enormous number of fine closely packed lines. The use of specially prepared emulsions in conjunction with spectroscopic instruments having optical systems of quartz has enabled the ultra-violet region to be very thoroughly studied and mapped. Another very important application of spectro-photography is in connection with astronomy. By means of photography we have been able to detect double stars that are so close together that the most powerful telescope would not reveal them

FIG. 4.



as two distinct stars. When one star is approaching us and another receding from us, each line in their spectrum will be doubled, the two new lines being one on each side of the single line that will be seen when both stars are moving at right angles to the line of vision. The line that is displaced towards the blue end of the spectrum represents the shortened wave length due to the approaching star, and the line displaced towards the red end the increased wave length due to the receding star. The rate at which the stars are moving from us or towards us can then be calculated from the displacement of the line. Fig. 4 shows spectro-photographs of the four typical stellar spectra, according to the classification of Secchi. Secchi made spectroscopic examinations of a very large number of stars and found that all stellar spectra could be classed under one or the other of four types. Secchi's Type I, or the Sirian type, includes most

of the bright white stars. Type 2 includes the solor stars; Type 3, the stars of reddish color, most of them variable stars. The spectra of stars of Type 3 show flutings or bands of lines sharply bounded on the violet side and falling off towards the red. It has been shown that these flutings are due to titanium oxide. Type 4 also consists of red stars with banded spectra, but the bands differ in arrangement and appearance from those of the third type and are sharply bounded on the red side. These stars are believed to have a comparatively low surface temperature, and the flutings are attributed to the presence of carbon. Passing now to the more purely astronomical applications, such as the photography of the sun, moon or stars: The planet Mars is particularly interesting to us, because it resembles in many ways our own terrestrial process. When either of the Martian polar regions come into view after being turned nearly a year away from the sun, it is found to be covered with a white cap. This gradually decreases in extent as the sun shines upon it during the remaining half of Martian year—sometimes nearly disappearing. This change is so obviously due to the precipitation of watery vapor in the form of ice, snow or frost during the winter and its melting or evaporation when exposed to the sun's rays, that such a conclusion has never been seriously questioned. The general sandy yellow appearance of Mars is considered to be due to vast deserts, and the green markings due to vegetation. Mars has been most thoroughly studied by means of photography, and much valuable data obtained.

Another very beautiful subject for photography is the great Nebula in Orion. The Nebulæ are luminous cloudy patches in the heavens. They resemble the stars in that they retain the same relative positions. When examined with sufficient telescopic power, a great many of these luminous patches are perceived to be composed of clusters of little stars. Fig. 5 shows a portion of the "Milky Way" to the north of Theta Ophiuchi. In this particular region are some of the most wonderful dark markings in the sky. Photography has been of inestimable value in the study of the moon, a very complete photographic chart of its various regions having been secured. By means of the spectro-heliograph, some very wonderful photographs have been made of solar prominences. These prominences are huge gaseous streamers flaring out from the body of the sun, and they are

frequently sixty to seventy thousand miles in length. The spectroheliograph is an instrument by which photographs may be made of the sun's body in light of any particular chosen wave length. The solar prominences are usually photographed in the monochromatic light of the red hydrogen line. Fig. 6 shows the 40-inch refractor at the Yerkes Observatory. It is with this wonderful telescope that most of the finest astronomical photographic work has been done. This huge telescope is capable of the most precise movement; clock-work and electrical devices

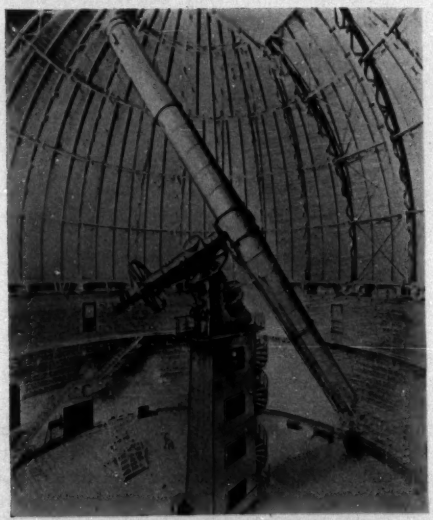
FIG. 5.

are provided by means of which the telescope may be made to follow exactly the path of a star. This is necessary in stellar photography, otherwise the image of the star would move across the photographic plate during the comparatively long exposure. By moving the telescope in unison with the star's movement, the image is kept perfectly still on the photographic plate. Photography has been of the very greatest use in the development of astronomy. A number of stars that are quite invisible through the most powerful telescope have been discovered and studied.

Another application of photography, which is of considerable interest to scientific workers, is photomicrography—that is, securing a photographic record of the enlarged image seen through a

microscope. The ordinary lens is for this work replaced by the miscroscope itself. The camera is similar in all respects to an ordinary camera. One of the most important things in photomicrography is to secure adequate and critical illumination. In this work it is nearly always necessary to use panchromatic plates, for most microscopic objects are colored. By the use of proper color filters any particular portion of a microscopic section

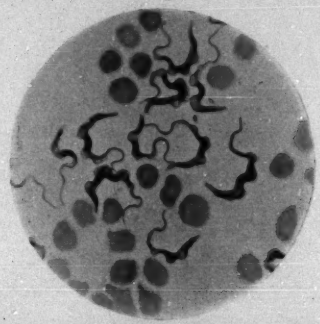
FIG. 6.



can be subdued or emphasized. This is important in connection with the rendering of structure. Photomicrography is applied to medicine in the study of pathological conditions, to bacteriology, insect anatomy, metallurgy and to many other industrial and scientific studies. Fig. 7 shows a photomicrograph of bacteria. These are the trypanosoma of sleeping sickness, found in the blood, and when in living condition actively motile by an undulatory movement of their protoplasm and a lashing of the flagellum. Photomicrography as applied to pathology is of great

importance. In practically every large pathological laboratory hundreds of photomicrographs of normal and abnormal pathological conditions are made yearly. These form a permanent record for the education of the student and the convenience of the pathologist. Such photomicrographic studies have brought about many improvements in the methods of detecting, treating and preventing organic diseases. Fig. 8 is an example of photomicrography applied to the study of insect anatomy. This is the tongue of the common house-fly, and is one of the most wonderful illustrations of the beauties of insect anatomy. The fly's tongue is the small black object which everyone has seen a fly

FIG. 7.

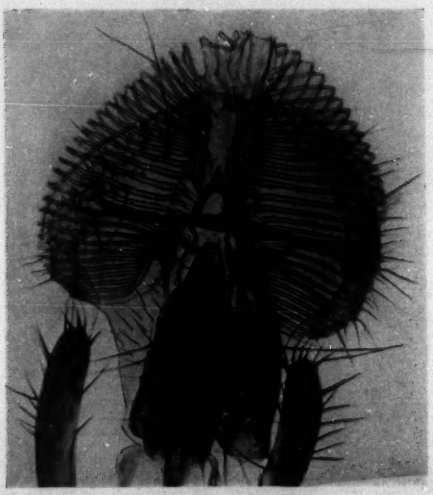


let down onto sugar, syrup or any of the sweet things he delights in. The large lobes contain the suctorial tubes; these tubes are wonderfully constructed. They have within them a spiral support very much like the coiled wire used for supporting and strengthening rubber gas pipe. The two brushes are those that he uses to clean up with after his meal.

One of the most valuable aids to medicine as a diagnostic agent is the practice of X-ray photography. Until quite recently considerable experimenting with apparatus and accessories was necessary for every operator before he felt at all confident of making a reasonably good X-ray photograph, but now instruments have been devised by which the time of exposure required can be determined with mathematical exactness and under all conditions, and it has become a far easier proposition to produce

really good radiographic plates. X-rays are produced by the discharge of a high potential current through a special form of vacuum tube known as a Crookes tube. There being no method of bringing X-rays to a focus, the images produced on a photographic emulsion are merely shadows of the object. The vacuum tube is brought within a reasonable distance of the patient in proper relation to the part to be photographed. The photographic plate in its black envelope is placed under the patient. The

FIG. 8.



exposure necessary varies a great deal, according to the structure of the part to be radiographed; also the vacuum tube must be chosen with a view to the results desired. A soft or low vacuum tube gives much better definition than a hard or high vacuum tube, as the rays pass less easily through dense substances and show greater differentiation of tissue. A very high vacuum tube may show but little difference between the bones and flesh, while a soft tube should give the minute structure of the bones. Most tubes in these days are fitted with regulators for controlling

the vacuum. Fig. 9 shows an X-ray photograph of a hand and forearm. Fig. 10 is a radiograph of the complete skull, and shows very nicely the details of bone structure. These radiographs were made with the instruments made by the Kny-Scheerer Company. For X-ray photography a special emulsion is necessary. It must be capable of giving contrast, and must be thickly coated upon the glass or celluloid support. In some cases, where the use of glass plates is awkward, owing to the shape or curva-

FIG. 9.

ture of the particular part to be radiographed, films may be used, and in dental radiography films are always used. In practically every large hospital there is a complete radiographic equipment, and regular studies are made of the bodily functions, particularly peristalsis. The patients are fed with a meal containing a substance which is opaque to X-rays, and therefore distinctly shown in the radiograph. By this means the process of digestion may be accurately studied.

As a source of amusement and pleasure the application of photography to motion-picture work is of great importance; but of still greater importance is the application of motion-picture

photography to scientific studies and for educational purposes. Motion-picture photography is now being used for recording surgical operations. The efficiency engineer uses it for motion study, and it is of the greatest use in teaching biology, natural history, chemistry, physics and countless other subjects. Governments of practically all nations have official cinematographers whose duty it is to record events of national and historical importance. These are preserved in vaults for the benefit of posterity, and will undoubtedly be of the greatest importance to future

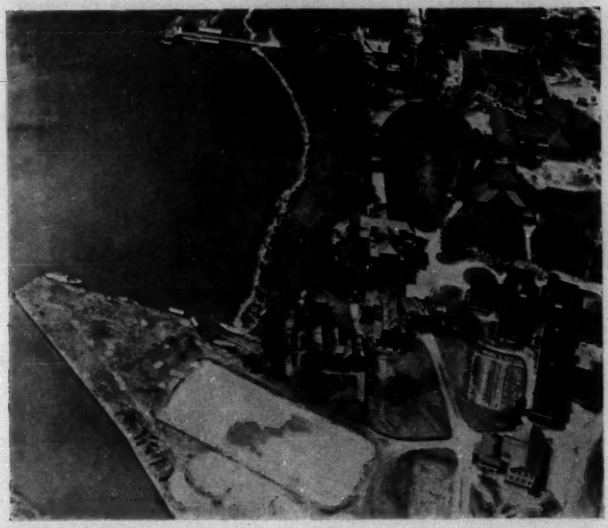
FIG. 10.

historians. Forestry and agricultural conditions are also recorded in motion pictures by various bureaus of the United States Government.

The war has perhaps done more than anything else to bring about improvements in photographic practice. Photography has been of such vital importance to the successful prosecution of the war that the best brains have been working upon the improvement of the various photographic processes. Aeroplane photography has perhaps been of the most direct service in the war. It has made it impossible for the enemy to carry out any extensive movement without detection, and the aerial photographs secured

of enemy territory have been of the utmost use in securing the success of our attacks and the safety of our men. It has been my privilege to be associated with the Signal Corps and the Science and Research Division in a great deal of experimental work in connection with war photography. Much of this work has been directed towards the production of suitable emulsions

FIG. 11.



for aeroplane work. For instance, emulsions which will detect all the colors used in camouflage and specially sensitive emulsions so that photography may be carried out on hazy days when the unaided eye sees practically nothing. From the very beginning the work has been of absorbing interest, and led to a great deal of physical and photographic research. Through the courtesy of the Military Censor, I am permitted to publish one or two illustrations of aerial photography. These are illustrated in Figs. 11, 12 and 13. These pictures show the wealth of detail that can

be secured when photographing from a plane. It is such pictures that have revealed the enemy's trench system, their gun emplacements, and have shown our officers the lay of the land, so that they might the better direct their attacks. Early in the war aerial photographs were made at an altitude of seven or eight thousand feet, but with the increasing range of anti-aircraft guns it became necessary to adopt a much higher altitude for photo-

FIG. 12.

graphic observation, and recently most pictures have been made at from twelve to fifteen thousand feet. There is no doubt that this country and her allies are going to take advantage of the many uses of photography to a much greater extent than before the war. Aerial photography will undoubtedly be used in the future to replace the older methods of survey and mapping. Some wonderful cameras have been constructed for aeroplane photography—some of them operated by hand in the ordinary way, and some of them automatic, the exposure being controlled

from the instrument board of the plane. One of the finest automatic cameras—the Brock camera—was developed and made in Philadelphia. Only a few of the many applications of photography have been discussed in this paper, and these only in a superficial way, without entering into any details of the photographic theory and practice involved. To deal fully with the many applications of photography would fill many volumes. In addition to

FIG. 13.

the few applications of photography discussed, it is used for such subjects as meteorology, the study of cloud formation, and the photography of lightning. By means of the telectrograph, photographs may now be transmitted over a telegraphic system. Photography is used for the recording and detection of criminals. A camera is the constant companion of the explorer, and the trusted recording medium of the naturalist, the geologist and other scientific workers. In fact, photography is now generally recognized as the accurate and invaluable recorder of progress in science, art and industry.

THE CONCEPT OF RESILIENCE WITH RESPECT TO INDICATING INSTRUMENTS.*

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I. CLASSIFICATION OF INSTRUMENTS.

For the purposes of the present treatment, measuring instruments may be grouped in the following large classes:

I. Indicating instruments.
   1. Index-and-scale instruments.
   2. Comparison instruments, read by reference to a fiducial mark.

II. Value-controlling instruments, usually non-indicating.

III. Totalizing, aggregating or integrating instruments.

Class I–1 includes instruments using a mechanical pointer or indicator traversing a fixed scale; instruments in which the kinematic relation is reversed, wherein a scale moves past a fixed pointer or reference mark; and instruments in which a surface of discontinuity, such as a liquid meniscus, traverses a fixed scale (as in barometers) or a moving scale (as in hydrometers). In each case the motion of the index relative to the scale may be one of either translation or rotation or of any required combination of the two.

The class of comparison instruments (I–2) overlaps the index-and-scale class in most cases, since a graduated scale having a short range of value equivalents is commonly applied at either or both sides of the fiducial mark or zero, as is familiarly instanced in the case of the precision balance. The graduated arc over which the pointer plays typifies the scale of an indicating instrument used for a range of capacities normally but a minute fraction of the total working capacity of the balance, which if the graduations other than the zero be omitted becomes a comparison instrument, strictly. This short-range indicating feature usually appears on comparison instruments for the reason that, exact equivalence of any two quantities being a practically impossible occurrence, it is desirable to know, except in the roughest commercial meas-

* Communicated by the Director, U. S. Bureau of Standards.

urements, not merely that the quantities compared are equivalent, but the amount of the deviation from exact equivalence, as a differential value or correction.

Class II includes instruments most familiar to the engineer, such as carburetors, wherein the flow of air is to be accommodated mechanically to the flow of fuel; thermostats and hygrostats; voltage regulators; automatic damper regulators for boiler furnaces; governors for steam engines, spring motors and other prime movers—and many others.

The instruments of the last main class (III) will not be further considered in the present discussion. This class comprises those in which the indication afforded represents the accumulation of values registered up to the time of observation. As examples may be mentioned gas and water meters, watthour meters and clocks.

The treatment of the present paper is particularly concerned with the instruments comprised in Classes I–1 and II, but relates also to a limited extent to that part of Class I–2 in which the combination of the scale and comparison instrument occurs in the manner already exemplified.

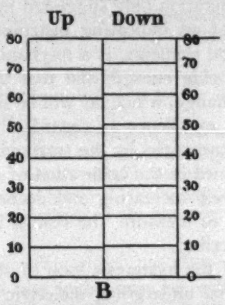
In an earlier paper [1] the general principles underlying the definition and determination of those types of variant errors in the indications of mechanical measuring instruments inherent in the defects of the instrument itself, and not *per se* indicative of change in the value of the quantity undergoing measurement, were discussed. To errors of this type I have applied the term *variance*. They typify the sort of errors which are not subject to avoidance by the application of corrections in the ordinary sense of the word, and have in the past been somewhat loosely referred to, when mentioned at all, as instrumental vagaries or perturbations. It was shown in the paper above referred to that the variance could be well expressed by plotting the relation between the quantity undergoing measurement and the indication of the instrument for a series of gradually increasing and then decreasing values of the former, so obtaining a representation of the deviation from consistent indication in the form of a hysteresis loop.

An interesting independent corroboration of the results shown in the previous paper with regard to the general form of the

[1] "Variance of Measuring Instruments and Its Relation to Accuracy and Sensitivity," Scientific Paper 328 of the Bureau of Standards.

calibration loop was found in the literature of the steam engine indicator. The appended Fig. 1 is reproduced from the diagram on page 179 of Houghtaling's "Steam Engine Indicator and Its Appliances." It represents the calibration of an indicator carried out by causing the pencil to trace a short line at each of a designated series of known unit pressures applied to the piston, for a cycle of increasing and decreasing values of pressure. It will be noted that the pairs of lines corresponding to a given pressure, while coincident at the lower and upper ends of the scale, are somewhat displaced mutually at the other readings, and that they tend definitely to a wider mutual displacement toward the middle or upper region of the scale. It is clear that if this particular calibra-

FIG. 1



tion were replotted with displacements of the pencil as ordinates and unit pressures as abscissæ, a loop of the type discussed in this and the previous paper would result, closed at the ends and widening out at the middle. Limitations of space prevent the reproduction of other experimental data tending to illustrate the characteristic closed loop, but it may be said that a large number of indicator calibrations giving results of precisely similar form are to be found in another text-book on the steam engine indicator.[2]

In this connection the steam engine indicator seems to afford a particularly fortunate corroboration, since that instrument comprises in a well-known manner, resulting from long development in the hands of able instrument makers, one of the most favorable

[2] See page 28 of "Practical Instructions for Using the Steam Engine Indicator," published by Crosby Steam Gage and Valve Company, Boston, 1917.

types of elastic force-resisting elements (usually a helical spring) in combination with an indicating train consisting of a linkwork of several jointed bars driving a frictionally opposed recording pencil—so that the indicator assuredly comprises causes of hysteresis associated with both elastic and mechanistic[3] phenomena. The indicator then, in this sense, may be deemed typical of indicating instruments generally in so far as any one instrument can be said to represent a group comprising a diversity of constructional elements and combinations.

II. HYSTERETIC CYCLES—THE PROPERTIES OF THE GRAPH—THE NATURE OF INSTRUMENTAL HYSTERESIS.

In the present paper it is desired to give more detailed discussion to the consideration only suggested in the previous work, *viz.*, the concept that an indicating instrument, in so far as it consists of mechanical elements, is a mechanical complex capable of storing and restoring energy, and that the perfection of its resilience in this exchange, which, as will be shown, may be taken as a measure of its excellence as regards the invariance of its indications, is to be measured by the smallness of the area of the hysteresis loop obtained in the calibration of the instrument over a range of successively increasing and decreasing values of the quantity which it is to measure, the results being plotted in the manner already described.

As in the case of the hysteresis loop of strained quasi-elastic bodies and of material undergoing dielectric or magnetic induction, the hysteresis loop obtained when an instrument is subjected to a complete cycle of operation represents by its area, generally speaking, the amount of energy lost or dissipated during a cycle.[4]

[3] The term "mechanistic" is used to characterize phenomena due to the mechanism itself, and not to the single components of the mechanism. Its use enables us to discriminate, for example, between causes of lag arising in imperfect elasticity and those due to imperfect mechanical operation of the linkwork considered as a mechanism.

[4] If the instrumental lag does not involve a significant time effect, the input of energy represented by a given slow deflection is a quite definite quantity or at least can be specified to lie within certain determinate limits. (This is a reasonable supposition in any event, but the author hopes to establish its verity on a sound experimental basis in a forthcoming paper. If a time lag intervenes, the energy loss in the instrument of course depends upon the frequency of the cycle, just as it does to a certain extent in other hysteretic phenomena, such as the stress-strain relation of such substances as rubber, leather, etc.)

Turning to Fig. 2, we are enabled at once to set down certain simple and useful relations and definitions which will be of value in gaining the greatest amount of information from the complete calibration curve (of two branches, forming a closed loop) for any given indicating instrument. For the sake of generality, an instrument affording both positive and negative indications has been assumed, such as might be typified by a dynamometer so constructed as to measure both traction and thrust, or an ammeter provided, as is not uncommon, with scales reading in opposite directions from a central zero.

Area $BCDD'_y$ =○= (equivalent to) energy required to produce deflection D_y when quantity undergoing measurement changes from B_x (−) to D_x (+).[5]

Area $BEDD'_y$ =○= energy returned to agent producing the original deflection upon return of the quantity undergoing measurement to the value B_x.

Area $BCDD'_y$ − area $BEDD'_y$ = area $BCDE$ =○= energy dissipated in the instrument during the cycle = E_h.

K_xL_x = the range of values of the quantity measured for a given deflection K_y.

M_yN_y = the range of deflection or indication for the value M_x of the quantity undergoing measurement.

OC and OE = respectively, remanent deflections or sets when quantity undergoing measurement is reduced from $-B_x$ to zero and from $+D_x$ to zero.

OS and OR = respectively, residual values of quantity undergoing measurement when deflection is reduced from $-B_y$ to zero and from $+D_y$ to zero.

Efficiency of resilience, or resiliency of the instrument over the cycle BDB = $\frac{\text{area } BEDD'_y}{\text{area } BCDD'_y}$

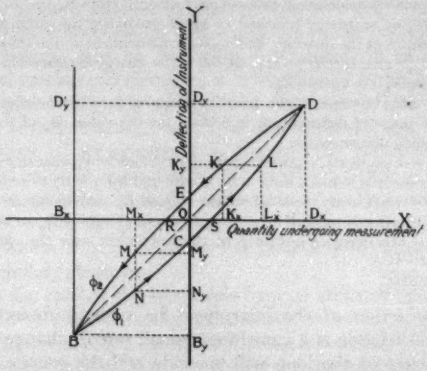
If the action of the instrument be without molecular and mechanical friction at a vanishingly small rate of change of x, the two branches of the loop will coincide and the energy returned to the deflecting agent upon completion of the cycle will be equal to that required to produce the deflection, this being the ideal case sometimes nearly approximated in instruments of the most excellent properties. (In purely optical systems the approximation is perfect, so far as is now known.) When this condition obtains, the resiliency becomes unity and the system a conservative or non-dissipative one. Moreover, the "apparent sensitivity," as determined from the slope of either the upward or downward

[5] It should be noted that in addition to the energies discussed in this and the following paragraphs, certain current-using electrical instruments require a continual supply of energy to maintain the deflection, due to the special characteristics of the type of instrument in question. However, this is not true for example of electrostatic instruments.

branch of the loop (now reduced to a line), becomes single-valued and equal to the inherent or "virtual" sensitivity; the deflections of the instrument are then perfectly reproducible and independent of its previous operational history.

It may be desirable to consider the actual nature of the energy loss in the instrument, which can be illustrated by a simple example. Consider the case of the familiar pressure gage of the Bourdon tube type. As the pressure in the closed system to which the instrument is connected is gradually increased, a deflection, more or less elastic, takes place in the Bourdon tube, which drives

FIG. 2



the indicating train and thence the pointer; the deflection of the pointer represents to some scale the energy supplied to the instrument by the source of pressure (aperiodic change of both x and y being assumed throughout the cycle). When the applied pressure is relieved, the deflection reduces to approximately its initial or zero value, while the stored energy is only in part returned to the agency which first supplied it. Clearly, however, as was illustrated in detail in the author's earlier paper, the forces in the gage opposing the applied pressure are at every point somewhat smaller during the period of release of pressure than during the period of its application, the difference obviously representing the

resultant of the forces of friction (molecular friction in the Bourdon tube, and friction of sliding in the elements of the instrument linkwork). A source of difference in the forces obtaining in the two parts of the cycle, related to and dependent upon the latter of the two causes just mentioned, arises in the change in the moment arms of levers, gears, etc., consequent upon the kinematic change in the relations of the centres of relative motion of journals and bearings, also discussed in the earlier paper. It was there shown that these shifts always act in such a manner as to reduce the restoring forces available within the instrument on the downcoming branch of the calibration curve as compared with those obtaining on the upgoing branch, and so contribute to a separation of the two branches evidenced as a hysteresis loop.

III. EVALUATION OF THE HYSTERESIS LOSS.

Since in every indicating instrument the motion of the indicator through any displacement—whether rotational or translational—implies the existence of a motive force to bring about such displacement, opposed by an equivalent reactive or restoring force, the essential coördinates of a work diagram apparently always exist. When the form of the function connecting the restoring force and the deflection of the indicator has once been determined, the results of the cyclic calibration described above can readily be plotted and measured in units of work dissipated in the instrument over the range of operation under consideration.

In the case of any particular instrument, then, the loss of energy consequent upon imperfect reversibility of the instrument operation can be calculated from the complete calibration curve when certain constants of the instrument are known. In the simple case of an ordinary spring scale, or Jolly balance, the area in dyne-centimetres of the calibration loop obtained by plotting load against deflection of the spring gives directly the energy loss in the cycle of operation under consideration, thus using the notation of Fig. 2:

$$E_h = \int_{B_y}^{D_y} [\phi_1(y) - \phi_2(y)]dy$$

In this case, of course, as in the figure, the *normal* relation between load and indication is sensibly a linear one. In the case of an

ammeter,[6] the energy stored in the instrument when a full scale reading is obtained is (*neglecting friction*) equal to the stiffness of the hairspring expressed in torque per unit deflection of the pointer, multiplied by the angle through which the pointer has turned. The displacement factor of the lost-work diagram bears its direct equivalence not to the reading in amperes, but to the actual pointer deflection in units of angle. If the instrument were without friction, either mechanical or molecular, the energy represented by any slow, aperiodic deflection would be precisely equal to the electrical energy taken up from the circuit in producing the deflection, neglecting the energy loss due to the heating effects of current flow. Likewise in returning to a zero reading, the instrument would restore to the circuit, if it remain connected, an amount of energy equal to that applied in producing the deflection. Actually, the excess of energy drawn from the circuit on increas-

[6] The following analysis, for which I am indebted to Dr. F. B. Silsbee of the Bureau of Standards, of the energy exchange involved in the deflection of a direct current electrical instrument shows in detail the mechanism of this transfer of energy from the current which is measured, to the measuring instrument: Consider a rectangular coil of n turns, having dimensions $l \times 2r$. A permanent magnet provides a magnetic field of strength H assumed uniform and radial. To compute the sensitivity we have for the side thrust on unit length of wire carrying a current I in a field H, $F = HI$ (1). Hence the torque on the entire coil is $\tau = 2HInlr$ (2). When the coil is at a steady deflection θ, this torque is balanced by the restoring torque of the spring $\tau = K\theta$ (3). Therefore by (3) and (2) the sensitivity $S \equiv \frac{\theta}{I} = \frac{2Hnlr}{K}$ (4).

To compute the energy which must be supplied to the coil electrically to produce the deflection (*i.e.*, the amount over and above I^2Rt required to maintain the deflection) we must compute the back electromotive force produced by the motion of the coil. For a unit length of wire moving with velocity v across a field of strength H, the induced emf is $e = vH$. Since $v = r\frac{d\theta}{dt}$, the total emf in the coil is $E = 2Hr\frac{d\theta}{dt}nl$. The rate at which energy must be supplied to force the current I against this back emf is $EI = 2HInlr\frac{d\theta}{dt}$, and the total energy required to produce the deflection θ is $W = \int EIdt = \int 2HInlr\,\frac{d\theta}{dt}\,dt = 2Hnlr\int Id\theta = SK\int Id\theta$ (5). For a gradual increase of current $I = \frac{\theta}{S}$ by (4), and therefore, from (5) $W = \frac{K\theta^2}{2}$ which shows that, neglecting dissipation by friction, all the energy is ultimately stored as potential energy in the spring.

It is interesting to note that if instead of a gradual application of current, a constant current I is *suddenly* applied, eq. 5 gives $W = SKI\theta = K\theta^2$, *i.e.*, twice the former value. The additional energy is of course dissipated in the damping of the instrument before the coil settles down in the deflected position.

ing current is equal to the electrical equivalent of the friction loss for the upgoing branch of the cycle, while the deficiency of electrical energy returned to the circuit on decreasing current is the equivalent of the friction loss for the downcoming branch of the same cycle.

As in the case of the ammeter, a hysteresis loop properly expressing the energy dissipation may often be obtained by referring the deflections not to the actual reading scale of the instrument, but to a uniformly divided scale, substituted for the purpose of the determination, for that provided on the instrument. Generally speaking, this will give the desired result, since, although the relation between the quantity which the instrument is to measure and the scale of graduations expressing that quantity may not be linear, that obtaining between the resisting force or torque and the deflections themselves in units of translation or rotation, usually is linear on account of the common practice of using, for the sake of simplicity, resistor elements having a closely linear stress-strain relation, such as hairsprings, torsion wires, plate springs or diaphragms, helical extension springs, or pendulum elements undergoing small deflections (such as the beam of a balance), etc. Thus, even in a centrifugal flyball or inclined-ring tachometer in which the relation between rotational speed and deflecting torque is very likely far from a linear one, the relation between torque and angular deflection of the pointer will be linear if the resisting torque is centered in one spring at the indicator spindle. If, as is often the case in tachometers, the resisting force is localized in two places, separated by links not having linear velocity ratios, the total resisting torque and the proportions of the total resisting torque assumed by the indicator hairspring and the governor spring, respectively, may differ for every configuration of the system. In such cases the lost work may whenever necessary be evaluated by kinematic analysis of the mechanism discussed on the following page.

Similarly, in the case of a vapor-pressure thermometer, the graduations are distinctly non-uniform on account of the non-linear relation between temperature and vapor-pressure, yet the *vapor pressure-angular deflection* relation will in the usual designs be found to be a linear one. To set up a linear relationship between deflection and temperature in such an instrument has not in the past been deemed practicable on account of the kinematic

complexity which the obtaining of such a relation would involve when conventional linkworks consisting of lower pairs and gears are utilized. In such an instrument, then, the required work diagram would be obtained by plotting not temperature against reading, but rather vapor pressure corresponding to temperature, against angular deflection of the indicator, thus affording the requisite coördinates of force and displacement. To generalize on this matter is somewhat difficult on account of the unavoidable complications introduced by the diversity of types and mechanical construction of instruments. It is believed that when due consideration is given the mechanism of the particular instrument, no difficulty will be had in any given case in arriving at the proper basis for the work diagram.

As a useful example in this connection may be mentioned an instrument in very wide use, namely, the steam engine indicator, in which the linkwork usually used to connect the piston and the recording pencil affords only an approximately straight-line relation between the displacement of the indicator piston and that of the recording pencil, hence between the load on the indicator spring and the displacement of the recording pencil. To arrive at a precise expression for the displacement at the recording pencil for any given displacement of the indicator piston, an exact determination of the approximation referred to is required and will, of course, involve no great difficulty, being obtainable with ease graphically when analytical methods are arduous. In this particular case the error is not great, and in fact must not be great if the autographic diagrams drawn by the instrument in actual use are to be evaluated without the necessity of continually applying complicated corrections. It is interesting to note that in the case of this instrument, the obtaining of an exactly linear relation between the displacements of piston and pencil has always been associated with the use of higher pairs, such as a cam-plate and roller, which as carried out in existing forms of steam engine indicators has undoubtely involved a marked increase in the friction losses.

Setting up the proper coördinate screen to obtain a calibration loop capable of expression by direct planimetry, in units of work lost in the cycle, involves then only a knowledge of the stress-strain or force-displacement relation of the elements affording the resisting agency of the instrument and of the kinematic function

expressing the displacement or "velocity" ratios of the elements of the linkwork.

IV. THE APPLICATION OF THE HYSTERESIS DETERMINATION.

1. THE CYCLIC STATE.

(*a*) *Aperiodic Change in the Variables an Essential.*—In the study of hysteresis phenomena of instruments it was noted that constancy in the outline and area of the hysteresis loop required that the change of values around the cycle between extreme points of reversal be always in the same direction. By implication, this requires that the motion of the indicator or pointer be aperiodic[7] or, practically speaking, slow, since if the rest-point be attained only after oscillation, the parts must necessarily have traversed a retrograde deflection. In fulfillment of the same requirement, the determination of the hysteresis of an instrument is to be carried out in the absence of all jarring and vibration.

This fact, as well as the necessity of getting the specimen into the cyclic state, is apparently well known in the case of magnetic hysteresis, and was thus noted in Hallo and Land's "Electrische und Magnetische Messungen and Messinstrumente" with regard to the recording of the magnetic hysteresis loop: "Alteration of field in the wrong [reverse] direction makes the whole series of observations useless."

It would appear from the magnetic analogue, and more definitely from experiments which the author has now in progress relative to this matter, that a reversal between the chosen end-

[7] It is to be noted that causing the indicator to approach its rest-point with a slow, aperiodic motion has the effect of eliminating as disturbing factors: (1) damping resistances afforded by fluid friction or friction having similar characteristics; (2) kinetic effects of mechanical friction, such as are directly or indirectly occasioned by oscillatory motion about a shifting rest-point, such that the rest-point becomes indeterminate in dynamic operation of the instrument; (3) time lag engendered by the inertia of the mechanism, a lag of rate of deflection behind the rate of change of the independent variable, depending primarily upon the rate of that change. All indicating instruments have a period of oscillation determined by the magnitude of the restoring force at the particular reading and by the magnitude and nature of coupling of the masses involved, so that even apart from the double-valued form of the aperiodically determined hysteresis function, the instrument indication at any instant is not uniquely determined, when the indicator is in motion, by the instantaneous value of the independent variable.

points always has the effect of cutting in on the normal loop[8] that would otherwise be obtained.

The necessity for the continuous aperiodic change of the variables will be clear when the general nature of hysteretic cycles is recalled. The coördinates of any point on such a cycle are a function not only of the value of the independent variable then obtaining, but also of the previous cyclic history.

(*b*) *Regularization Antecedent to Calibration.*—It necessarily follows, moreover, that the specimen under consideration, whether it be a magnetic body, a structural element under stress, or an instrument undergoing calibration, must first be *accustomed* to the cycle under investigation by being "stressed" and relieved a number of times over the same cycle.[9] By this procedure the previous and unknown history is, so to speak, obliterated and the mechanism is regularized in that the parts, whether molecules or finite mechanical elements, are set into stable and more or less perfectly reproducible relationships,[10] which, however, are immediately disturbed and disestablished upon reversal of the "stress" before the chosen end-point is reached.

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[8] As it is hoped to demonstrate in detail in a later paper for which the experimental work is now practically completed, this normal loop is a maximum of all obtainable for any two turning points lying between the chosen extreme turning points, and, moreover, completely encloses and circumscribes all such minor loops, a circumstance which, if definitely demonstrable, involves conclusions that will be of great value in exact utilization of instruments as well as in their testing, and will, for example, open the way to precise autographic determination of the hysteresis cycle of an instrument without anomalous distortion of the results by the hysteresis of the autographic recording apparatus itself.

[9] The cyclic state with respect to stress strain loops for steel under tensile and compressive stress is discussed in some detail in "Stress-Strain Loops for Steel in the Cyclic State," by J. H. Smith and G. A. Wedgwood, *Journal of the Iron and Steel Institute*, 1915, xci, p. 365.

[10] So far as experience and analysis are now available to guide us, the cyclic state can be set up in all indicating instruments except those in the following two categories, in both of which special treatment is necessary: (*a*) those in which a sensible time effect intervenes, or in which transient phenomena are of importance even at rates of change of indication which are markedly slow. (The aneroid barometer, it is believed, is such an instrument.) (*b*) those in which an uncompensated backlash exists, in which circumstance the indicator is definitely unconstrained (in the kinematic sense) for some or all configurations of the mechanism. This case, which is a very interesting one, will be discussed in a later paper.

2. THE INDICATIONS OF AREA AND FORM OF THE HYSTERESIS LOOP.

It will readily be seen that of two instruments operating over the same range of indication, that is the better which has the smaller mean hysteresis per cycle, except for the following factor, which is practically of secondary importance, and will not fail of being noted in the calibration, *viz.*, the shape of the hysteresis loop—of exactly analogous import to the form factor in statistical distributions. In the case of one instrument, a regular, smoothly outlined hysteresis loop may be obtained, with a fairly large displacement between its branches; in another the branches of the loop may in general tend to lie much closer together, and yet at some portion of one or both branches an abnormal divergence will appear, due, let us say, to binding or sticking of the mechanism, as may easily occur from local bad fitting or misalignment of parts. While, even with this local divergence in the two branches of the hysteresis loop, the second instrument may exhibit a notably smaller total energy dissipation—it may be the less serviceable of the two, since under certain conditions or accidents of use the high local variance may be of serious import. Clearly, then, we must define both aggregate (or mean) energy loss, as in dyne-centimeters per unit change of the independent variable, and *distribution* of energy loss. The latter may perhaps best be expressed by such a term as *maximum energy dissipation*, again in dyne-centimetres, per unit change of the independent variable. Such a term, then, fills somewhat the same function as does *extreme deviation from the mean* in characterization of statistical distributions.

3. EFFECT OF VIBRATORY TREATMENT.

When vibration treatment is employed to minimize frictional lag in instruments, the portion of the hysteresis loop which is effaced thereby represents in part the contribution of energy from the vibrating agent that has been made available in the instrument. The amount of the diminution of the hysteresis loop occasioned by properly applied vibration treatment is nothing less than astonishing, and in some cases where the instrument is sufficiently rugged to withstand vibration of considerable amplitude and energy the variance can by such treatment be reduced to a few per cent. of its value in the untapped condition. The

writer would hazard the suggestion that certain types of instruments might well be provided with in-built mechanical or electrical vibrators, which would assure both the proper orientation and the required amplitude of vibration.[11] Reasoning from analogy, there seems to be cause to believe that vibration treatment will also reduce the hysteresis effects arising from imperfect elasticity or other molecular causes or even irreversible time effects or drifts. Certainly it is true that in the case of magnetic and dielectric hysteresis and dielectric time lag, each of the effects is modified by jarring, in a very definitely measurable amount and rate, as reported by Ewing and Kohlrausch for magnetism and electric charge, respectively. The effect of vibration treatment on plastic lag is an interesting study whose further elucidation is to be hoped for.

4. THE OCCURRENCE AND CAUSES OF HYSTERETIC LOSSES IN LIQUID-COLUMN INSTRUMENTS.

Experimental data which would permit of a satisfactory analysis of the energy losses associated with the motion of a liquid in an inclined or vertical tube, such as occur in the case of barometers and other manometers, are unfortunately lacking, and it is hopeless to discuss this matter in any detail in the present state of our knowledge of the subject. It seems certain that in

[11] Since writing the above, the author has come upon unexpected instances of actual utilization of the principle above suggested of applying to an instrument definite mechanical means for diminishing lag by a graduated and directed vibration—possibly in William Thomson's siphon recorder for cable telegraphy and certainly in the Cuttriss modification of that instrument. In the latter, persistent mechanical vibration of the recording pen or siphon to which is affixed a minute bit of iron, is produced by pulsations of flux in a subjacent magnetic field. The effect is to keep the siphon in continual vibration into and out of contact with the paper upon which it registers, with a fairly high periodicity; while drawing a graph that is practically continuous, the pen is, nevertheless, intermittently relieved of all constraint due to mechanical friction, thus performing substantially as well, as regards freedom from lag, as would a freely suspended galvanometer element. It is understood that a similar principle is incidentally applied in the telautograph, a slight vibratory motion of the writing pen being maintained by use of superposed harmonics on the sending current with the effect of reducing the frictional lag originating in the linkwork and in the contact between the recording pen and the paper. The author's attention has been directed also to a certain French-made watthour meter, in which is incorporated a small auxiliary motor whose function is to oscillate the brushes continually through a small angle, thereby greatly diminishing the effects of brush friction.

the displacement of a liquid meniscus or of the capillary surface about an emergent rod, a transfer of energies takes place apart from that involved in the velocity of the movement. How this depends upon the purity of the materials at the boundaries and upon the wetting or non-wetting of the surface of the tube has never been analyzed, so far as the writer knows. In the case of the spirit-level, the circumstances seem especially to favor a minimum of intransient irreversibility, since the condition of the system as regards the wetting of the surface of the tube and the vapor tension in the entrained bubble, etc., may be expected to undergo the very minimum of alteration during the assuming of a new rest-point by the bubble. Consultation with experts in the use of astronomical and geodetic instruments has elicited only the information that it is considered necessary to tap the tube in taking observations in order to obtain the most reproducible results, suggesting that a sensible amount of lag was considered to intervene, although exact studies of such lag and information as to its amount are lacking.

Another observer experienced in the use of the astronomical level has stated that not only does perceptible lag probably occur, but that he has frequently noted a step-by-step advance of the bubble, very suggestive of static frictional resistance, in that the bubble will seem to have stopped completely and will then advance a short interval, repeating this possibly a second time in a manner not dissimilar to that familiar in more common and less delicate mechanical instruments.[12] This observation, of course, if it be correctly recorded, represents one sort of manifestation of passivity effects, discussed in greater detail in the earlier paper.

Inquiry was made of the Coast and Geodetic Survey with regard to the spirit-levels used on precision surveying instruments,

[12] This intermittent motion of a fluid element, striking and anomalous though it may seem, has been observed by Gore ("On the Capillary Electroscope," Proc. Royal Society, 1879, Vol. 30, page 32), and discussed in some detail in the above paper. He ascribes it, in the case of the capillary electrometer, "to a sudden increase of mechanical resistance, usually caused by unequal adhesion of the mercury to different parts of the tube, but sometimes by a minute trace of solid substance in the tube. With a very feeble current this adhesion shows itself in several ways, usually by a more or less sudden retardation or stoppage of the motion of the mercurial column, by a delay in its commencement of motion, or by its non-movement." By adopting certain changes and precautions he found, he continues, "that the mercurial column, instead of moving from point to point with a jerk and stopping suddenly, moved with a gradually diminishing speed until it stopped."

and information was received that the existence of lag in level-tubes is realized in that service, but that its magnitude has not been measured. Moreover, the statement was made that tapping of the instrument to reduce the effect of the lag was impracticable for their purposes, on account of the possibility of thus disturbing the constancy of the relation between the axis of the bubble and the line of sight of the instrument. However, the method of observation used was such that by reversal of the level-tube the bubble was brought to rest from opposite directions (with reference to space), so that if only the lag remained constant, its effect on the accuracy of the observations would be practically eliminated.

Experimental information in regard to intransient irreversibility in the case of level-tubes would be of definite value in many lines of engineering and physical work.

In general, the tendency to assume that instruments employing a liquid meniscus are sensibly without variance is not a safe one, for it is well known that a marked hysteresis exists even in the case of hydrometers used with all due precautions with respect to cleanliness of surface and constancy of temperature. For example, the section of the Bureau of Standards dealing with calibration of volumetric glassware has reported that in sensitive hydrometers having a slender stem and large bulb, graduated to .0001 (specific gravity) over a range of about .0150, the variance may amount to 2 or 3 divisions under the best laboratory conditions, while in commercial use it may easily be much greater. Even this variation, moreover, would probably be increased were the instrument required to assume its final reading without oscillation. The same type of variance has been noted in differential, two-liquid manometers, when they are so adjusted as to be very sensitive.

Assuming as a specific example the ordinary liquid column manometer, it is clear that as the meniscus travels along the tube a change in the shape and area of the free surface must take place. This action may account for the imperfect reversibility of the calibration of such an instrument in one or both of the following ways: The change in the meniscus will certainly involve the occurrence of the effect well known in inverse form in the capillary electrometer, producing a change in the electric potential. Moreover, William Thomson determined the thermodynamic transfer following such changes in the configuration of

a free liquid surface, such that to keep the temperature constant when the area of the surface increases by unity, an amount of heat must be supplied which is dynamically equivalent to the product of the absolute temperature into the decrement of surface tension per degree of temperature, this being known as the latent heat of surface extension.

The significance of these two phenomena in relation to the present discussion lies in the fact that change in the one case of electrical charge, and in the other of temperature, would account in some measure for the irreversibility which has been noted in liquid column instruments, in that either change would in itself occasion a determinate alteration of the shape and tension of the meniscus. Considerable research would be required to evaluate these phenomena as they relate to instrumental hysteresis. It may even be that increasing the heat or electrical capacity and reducing the insulation of a liquid column instrument would notably enhance the reproducibility of its readings.

Apart from the possible causes above suggested, undoubtedly dirty, or in the case of mercury, oxide-coated liquid surfaces play an important rôle in the hysteresis loss of liquid manometers and hydrometers. Such a result is of course easily to be explained on the basis of irregularities in the value of the surface tension, irreversible on account of their accidental nature, and of a sort of solid, or better perhaps, granular friction manifesting itself whether at the bounding surfaces or in the mass of the liquid.[13]

5. EQUIVALENCE OF RANGE OF OPERATION A REQUISITE FOR COMPARABILITY OF RESULTS.

Reliable quantitative comparison of instrument performances by the use of the resiliencies computed on the basis of their hys-

[13] Reverting to the case of the capillary electrometer, there is no reason to suppose that Gore's modifications *totally* eliminated irreversible lag in the instrument, and, in fact, the contrary is undoubtedly the case, as is indicated by the evidence of the astronomical level where all practicable perfection of tube and purity of liquid are closely approximated, and in which, nevertheless, the existence of finite passivity seems established beyond question. Some aspects of this question seem to lead inescapably to the postulate that actual liquids are not sensibly perfect in the sense of the definition by which liquids are customarily discriminated from solids as being substances capable of persistent deformation under an infinitesimal value of shear, or in the terms of Maxwell's definition, as substances which, if the smallest force be long enough

teresis loops will require that the range of reading or operation for the instruments compared be the same or that the ranges used be reduced to the same basis by computation based upon a knowledge of the function connecting the range of operation with the area of the hysteresis loop. For example, in comparing a pressure gage of a capacity of 200 pounds/in^2 with one of 300 pounds/in^2, either the observations must be taken over a range common to both instruments, as for example from 0 to 200 pounds/in^2, in which case a portion of the range of graduation of one is necessarily discarded—or a factor must be found by which observations over the full range of the respective instruments can be reduced to an equivalent basis.

Some information is available with respect to a limited phase of this subject, from the researches of Rowett,[14] who made a valuable study of torsional hysteresis. According to Rowett, the energy dissipated in torsional hysteresis of steel is proportional very exactly to the third power of the range of stress to which the member is subjected. He noted also that the loss was sensibly independent of the frequency [which is equivalent to a statement that the hysteresis is without time lag]. These results will, of course, apply rigidly only to that portion of instrumental hysteresis contributed by torsionally stressed elastic elements such as torsion bar springs, filar torsion suspensions, helical springs under axial loading, etc., and on that account computation of hysteresis loops of most instruments to equivalency of range, when actually taken over diverse ranges, is not generally practicable except by experiment and extrapolation on the class of instruments in question.

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applied, will undergo a constantly increasing change of form. It may even be that complete liquidity (in the sense of perfect accordance with the above definitions of the liquid state) is not practically attained, even in the absence of cognizable dirtiness and granularity, and that there is no definite or sharp line of demarcation between existing viscous liquids and plastic solids. It is fitting to note that if the above surmise is correct, it is probably without present practical importance except in the case of measuring instruments of precise character, wherein alone the deviation from complete liquidity is observable, if it exists. The minuteness of the quantum under consideration is suggested when it is recalled that the intrinsic lag referred to in the case of the astronomical level becomes noteworthy only in measurements of angle tending toward a precision of a part in a million or more.

[14] F. E. Rowett, "Elastic Hysteresis in Steel," Royal Society Proceedings, Vol. 89A, p. 528, Dec., 1913.

V. PRACTICAL UTILITY OF THE METHOD—MEANS FOR IMPROVING INSTRUMENT RESILIENCY.

The hysteresis loop in instrument calibration, then, affords as important and necessary information as does the indicator diagram in engine testing. It permits the ready determination of the mechanical performance or "efficiency" of the instrument, referred to an ideal instrument completely devoid of friction of all kinds. The mean efficiency of performance of an indicating instrument can then be rated in terms of the completeness of its resilience, while a definite range of indication for any given value of the quantity measured, and a range of values of the quantity measured for any given indication can be directly scaled from the hysteresis diagram.

The practical application of the hysteresis determination in instrument testing may be regarded somewhat in the following way: In the ordinary method of calibration the errors are commonly determined at various points on the instrument scale, for change in one direction only of the quantity which the instrument is designed to measure, the instrument often being tapped at the time of reading in order to minimize the hysteresis effects. This method affords a means of selection between members of a group of instruments all of one type of design and construction, when substantial equality of frictional errors is assumed for all members of the group.

On the other hand, the determination of instrumental hysteresis under a condition of slow aperiodic change of indication and in the absence of jarring and vibration, enables one to differentiate between instruments of different types, so making possible the choice of that type which is *capable* of the best aggregate mechanical performance. With regard to the method first described, it may be said that the absolute errors of indication, expressed if necessary by a mean or average value, represent the result of the adjustments to which the instrument has been subjected; and, within limits, the mean of such errors at any point of the scale is alterable at will by changes in *adjustment* which are or can be provided for in the mechanical details of construction. Such changes in adjustment include alteration of the active length and strength of a restoring spring, change in the length or angularity of some link of the mechanism, alteration of the spacing of graduations or modification of the contour

of a cam. The variance errors, on the contrary, which are not eliminable by any of the above operations, afford a reliable criterion of the *characteristics of the type* of instrument, representing within the limits of course of individual variation, not so much the performance of a particular instrument as that of the class to which a given operating principle or mechanism pertains.

To alter the variance of an instrument we change not the adjustment, but the operating principle, the design of mechanical details, or the quality of the workmanship on the mechanism (as distinguished from the quality of workmanship evidenced in the carefulness and accuracy of adjustment). For example, reduction of the amount of relative movement of coacting parts will reduce the amount of the variance, other things being equal, since the displacement factor in the work equation is thereby reduced. Similarly, increase of the forces available to cause and resist respectively the motion of the instrument mechanism, provided that the frictional resistances do not rise in the same proportion, is efficacious in diminishing variance. For example, in a diaphragm pressure gage this end will be attained without change of the operating range by increasing the effective area of the diaphragm, if at the same time the reactive force is correspondingly increased. In an automatic weighing scale we attain the same end by reducing the leverage ratio, so that the force available to move the indicating train is increased in inverse proportion. By such changes, if, as is usual, the friction does not increase as rapidly as do the available motive and restoring forces, we accomplish a diminution of the proportionate effect of friction and improve the resiliency of the instrument. Variance may likewise be reduced by improving the fit and finish of coacting parts, as the journals and bearings, or by replacing a part having relatively high frictional moment by one having less, as in substituting a ball bearing or conical pivot for an ordinary cylindrical bearing.

It is to be noted that changes in adjustment intended to decrease errors of calibration will in general affect the variance, but only as an effect of smaller order. The adjustment may change the magnification or "velocity ratio" of the instrument and thereby increase or diminish the work of friction on account of the greater or less relative motion of the coacting parts for a given range of the independent variable. For example, an increase in the magnification of a pressure gauge intended to bring the indicator up to proper coincidence at the extremes of the gradu-

ated scale, effected by changing the working length of the adjustable link, will slightly increase the total friction loss, inasmuch as it involves a greater relative motion of the driving gear and indicator pinion.

Attention may be called to the fact that in choosing the particular form of turning pair to be used in an instrument, we are led normally not by considerations of sensitiveness, but of responsiveness—that is, freedom from the passivity of operation attendant upon the presence of friction; or, in a more general sense, we seek a minimum of hysteresis loss in a cycle of operation of the instrument. To be sure the fact that the hysteresis loss actually measures the "uncertainty" or "unreliability" of the indications of an instrument, in so far as this property is related to the mechanical construction, has hitherto failed of recognition; but it was of course perceived that this "unreliability" had its origin in frictional resistances of one kind or another.

It is the relatively perfect freedom from friction in the torsion suspension which has brought about its wide adoption in precise measuring instruments of great variety, together with the fact that in one element it comprises two essentials: the support for the rotation of the deflected element, and the means for resisting that rotation according to a definite and closely linear law. Thus it is that such a suspension, combining as it does in the same substance the motion-constraining and force-resisting elements, makes for minimum variance and passivity, and it is this property and not its "sensitiveness" which gives the torsion suspension its well-known advantage. The flexural suspension which has been employed in micro-balances and in precise mechanical length-measuring apparatus, also affords the combination of a load-supporting and force-resisting element, with the limitation that its angular deflection is practically required to be less in amount than in the case of the torsion suspension.

In making inquiries to determine what, if any, systematic utilization has been made of variance determinations in actual testing of instruments, one interesting approximation to this method of test was met with in factory practice. It was found that sometimes in order to arrive at an estimate of the friction in automatic weighing scales, a load of, say, one-half the rated capacity was placed upon the platform, and the pointer allowed under suitable damping gradually to approach its reading. The final reading attained being noted, additional load up to the rated capacity

was applied, and this latter increment then as gradually removed. The reading at half load again being noted, the difference between the two readings at this same load afforded a measure of the effect of friction at one region of the graduations. When the test load is equal to half the capacity of the scale the maximum vertical width of the hysteresis loop is thus approximately determined.[15]

VI. SUMMARY.

This paper deals particularly with those instruments of the index-and-scale and value-controlling types of the class of non-integrating instruments, as distinguished from integrating instruments and those used for comparison purposes strictly. Independent corroboration is adduced regarding the general characteristics of the hysteresis phenomena discussed in the author's earlier paper on the variance of measuring instruments.

It is shown that the area of the hysteresis loop obtained on complete cyclic calibration is a measure of the energy dissipated in the operation of the instrument and that the smallness of the area of this loop, which may be used as a factor in a function exactly analogous to the resiliency in the case of other quasi-elastic bodies, is a measure of the excellence of the instrument as regards the reproducibility or invariance of its indications, so far as concerns mechanical sources of variation. The specific properties of the hysteresis loop are set down analytically and the physical nature and causes of the imperfect resilience of instruments are discussed in detail.

Since the motion of an index or pointer through a displacement implies the existence of a motive force to bring about the deflection, in the presence of an equivalent reactive or restoring force opposing it, the essentials of a work diagram apparently always exist in the results of a properly performed cyclic calibration. Indications are given of the methods to be followed in the process of reducing the results of the calibration to such form that the loop obtained correctly represents energy dissipation during a cycle, typifying an integral of the form

$$\int_{B_y}^{D_y} [\phi_1(y) - \phi_2(y)]\, dy$$

[15] This information is due to the courtesy of Mr. H. O. Hem, consulting engineer of the Toledo Scale Company.

when B_y and D_y are the projections of the extremities B and D of the loop on the axis of deflection or reading.

The restrictions which surround the carrying out of cyclic calibrations in a manner calculated to obtain results of the character required are discussed, including the requirements of slow, aperiodic change of the variables, unreversed between the chosen extreme turning points, and accomplished in the absence of jarring or vibration. Attention is directed to the necessity of accustoming the instrument to the particular cycle over which it is to be calibrated, to the end of regularizing its performance.

Both the form and area of the hysteresis loop should be observed, in order to arrive at regional as well as aggregate effects of the causes producing the variance. The amount and scope of the effects of vibratory treatment in modifying and diminishing the causes of lag are indicated.

The possible causes of the lag known to exist in the case of instruments using a surface of discontinuity between fluids as the indicating element are discussed, and it is shown that known phenomena perhaps hitherto unrecognized in their relation to instrument design and calibration may account for the variancy noted. Detailed experimental consideration of these factors is hoped for.

Comparison of instrument performances on the basis of the hysteresis loss requires equivalence of the ranges of operation, or possibly reduction of the results on the basis of information not yet available in a form capable of general application.

The resiliency determination opens up a field for type-testing and selection of instruments on a basis quite discrete from that pertaining to the ordinary methods of calibration, in that the former permits selection between types of instruments rather than between individuals, making clearly discriminable the differences between the characteristics of given operating principles, designs of mechanical details, or qualities of workmanship. The more general methods of diminishing variance educible from the foregoing considerations are indicated.[16]

WASHINGTON, D. C., November 9, 1918.

[16] Since the above paper went to press, a portion of the experimental work referred to in footnote 8 has been given brief publication: *Journal of the Washington Academy of Sciences*, Jan. 19, 1919, vol. 9, No. 2, p. 38. Regarding footnote 10, section (*a*), see "Experimental Elasticity," G. F. C. Searle, Cambridge, 1908, where the mode of setting up the cyclic state in the case of phenomena involving sensible time effects is explained and illustrated.

The Industrial Chemist. A. HENWOOD. (*Drug and Chemical Markets*, vol. 5, No. 7, p. 5, October 23, 1918.)—The mathematicians have a phrase which applies admirably to all problems with which we may be confronted. It is their custom to speak of a set of conditions as "necessary and sufficient" for the solution of a problem. In the course of training which we commonly give our prospective chemists, we have undoubtedly recognized and applied many necessary conditions, but it is fairly open to question whether the conditions that have been recognized and applied are sufficient. The necessary and sufficient elements of a course of training can only be determined by a careful and accurate analysis of the environment in which the individual is to be placed. Too often the content of a course of training has been determined from preconceived requirements dictated by existent courses or by previous experience in fields none too closely related to the one under consideration. The result is that many necessary elements have been overlooked and many unnecessary elements have been incorporated which have consumed the student's time without developing in him the type of competency desired.

The graduate of the average chemical course, when he enters an industrial organization, finds himself in an environment utterly different from anything he has before experienced. He has certain elements of training which give him some degree of usefulness, but he lacks many which he must acquire by the painful and costly process of trial and error. His chemical training has not considered the limitations imposed by engineering conditions, and his engineering training has not been sufficiently influenced by chemical considerations which profoundly modify ordinary practice.

On the other hand, there are other elements not having directly to do with the transformation of substances or with energy which nevertheless are of first importance in the training of the industrial chemist. Moreover, it is just these subjects that are treated as of secondary importance by both student and faculty. One of the first requisites in an industrial organization is that its parts coördinate accurately. It is astonishing how purely technical subjects lose the supreme position they occupied in the academic world, and how problems of human relationship assume the position of importance. This can be easily verified by reference to the experience of any technically trained man who has entered the industrial field.

In the past, there has been a lack of coöperation between the school and the industrial organization; at present, this condition is undoubtedly passing away; in the future, it may be hoped that they will work hand in hand, the one being a continuation and fulfillment of the other. The best course of training for the industrial chemist cannot be proposed by any one man or by one group of men. It is a problem which will require and is worthy of the best and most active efforts of industrialists and educators. It would seem entirely possible for such a group to state the conditions "necessary and sufficient" for the training of an industrial chemist.

WINDMILLS, PICTURESQUE AND HISTORIC: THE MOTORS OF THE PAST.*

BY

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THE pessimist says that man is a lazy animal and that he invents machines to save himself work. The optimist, that man is an industrious creature who invents machines that he may accomplish the more. Whichever doctrine is right, there is but little question that of all the ingenious contrivances evolved by man none is more picturesque, of more historic interest nor of greater usefulness in its day than the old-fashioned windmill, the world's principal motor for some eight hundred years. And "motor" is the viewpoint to take of this old piece of mechanism, for just as the later devices of steam, electricity or gasoline are for the purposes of making power for the needs of man, so was this old appliance for the prime purpose of securing power from the wind, and by thus harnessing that most widely distributed of Nature's forces, of enabling the accomplishment of work far beyond the limits of manual power.

The steam engine came into use in the early part of the nineteenth century. By 1825 most of the principal English cities had it in use. Before that period, and dating back to remote ages, the only sources of power—other than man or bullocks, etc.—were the two great forces of wind and water. But only countries of waterways and varying levels afforded waterfalls; while the wind was universal. Therefore, while water wheels were in use in parallel periods with the oldest of windmills, in number they were infinitely less, so that one can properly say that the world's motor for some eight centuries was the old-time windmill. These eight centuries are from about 1000 to 1825, when, with the advent of Watt's invention, the zenith of windmill design and use had been attained. After that date they so declined that in fifty years not only had new construction ceased, but the old structures in very large measure had fallen into decay and

* Presented at a meeting of the Mechanical and Engineering Section, held Thursday, March 14, 1918.

abandonment. It is evident from the above that an account of this old, picturesque, historic and effective tool of mankind should have some interest, both from the standpoint of engineering and that of sentiment; and it is believed that what follows will give the essential facts relating to it. It may be proper to say here that what is related applies entirely to the old-style windmill, and in no measure whatever to the modern American type of windmill, which, while cheap, effective and useful, is nevertheless a prosaic, galvanized iron, squeaky thing, of which happily the larger proportion of the millions annually made is exported out of our country!

While the antiquity of windmills is traced by some back to the Romans there is really nothing very definitely known of their existence before the period of the Crusaders. They were said to have been brought into central Europe in that period from the Far East; though this is open to question. Practically their origin is lost in antiquity, and we only know that they appear in the earliest records as existent in some form or other.

But by 1200 they were well established. The first English windmill is of 1191. There are numerous records of them in the thirteenth century. There is a brass tablet of 1349 at Lynn church, with a windmill graven on it. In old stained glass of the early churches windmills are shown in some of the landscapes; as at Great Greenford and Fairfield. In a view, "London in the time of the Tudors" (1560), windmills are seen; and Great Windmill Street commemorates to this day the location of one in the past in that city. Elsewhere it was the same. Rembrandt, of the early part of the seventeenth century, shows such mills in some of his pictures; and in the early prints and views of France, Germany and other countries is abundant evidence of the use of these old, useful machines, in various forms, places and ways.

What was standard in the old world was naturally brought into the new, and so we find in America, concurrent with the colonies and settlements of the early days, the introduction and use of windmills. The Dutch in New Amsterdam, in 1625 and later; the Swedes on the Delaware, in 1643; the English in Rhode Island, in 1665 and 1675, and Boston, in 1660; and on the Carolina coast—all had their mills, as shown by early records, maps and views. And these mills were logically the types used by the

respective settlers, according to the district from which they had come. For instance, the old mill in Somerville, Mass., built in 1710 by Jean Mallet, a French Huguenot, is of the pure French type; as were those near Detroit, by the followers of the fortunes of Cadillac; while those in Talbot, Kent and Dorset counties, Maryland, reflected the clear English design of the old country. The same applies to the numerous ones erected in the colonial days of 1725 to 1775, in Easthampton, Bridgehampton, etc., on Long Island; at various points on Cape Cod; at Nantucket (1746); in numerous instances on Newport Island, Rhode Island, etc. A notable one of this type and period was that on Windmill Island in the Delaware River, shown in an old view, "An east prospect of the City of Philadelphia," 1746. All these reflected the English design of the emigrant settlers, bringing with them and promptly setting up and using the motors or machinery of the mother country.

There are two forms into which these old mills can be grouped, *viz.*, vertical and horizontal. By that is meant the relative position of the wheel and shaft. The vertical is that form in which the wheel is vertical, mounted on a shaft which is horizontal or nearly so. This is the form almost universal, for while various instances of the other have been tried, scarcely one in a thousand has been used compared with the vertical type. The reason for this is that in the vertical form of wheel, its face directly confronting the wind, all vanes are acted upon at once, and there is not only the greatest resulting power, but the greatest simplicity of construction and of operation and handling. The horizontal wheel, on the other hand, occupying a horizontal zone and attached to a shaft that is vertical, like the usual small water turbine, in position (but not in the fluid impact) receives the wind impact upon only some of the vanes at a time—not the whole circumference—with less proportional power and greater complexity of construction. So secondary has been the use of this style of windmill that consideration of it is negligible.

From the design standpoint, windmills involve four essential component parts:

(*a*) A tower, or means of support for the moving wheel and mechanism.

(*b*) A revolving wheel that receives the impact of the wind, converting it into power.

(*c*) Some means of turning the wheel, to follow the shifting of the wind; and,

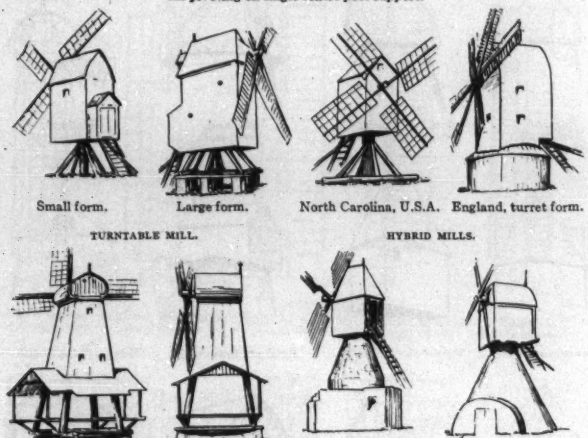
(*d*) The driven machinery.

(*A*) *The Towers or Supports.*—The support in the earliest form of mill was merely a post, made of a suitable log or tree trunk—sometimes 30 inches thick—upon which the entire structure was carried or hung and pivoted, so that it could turn freely to the wind. This was the original type—the old "post-mill," appearing in the earliest known prints and records, and alone used until about 1650. At that time the "tower mill" was developed, and this, of larger possibilities, soon resulted in great structures of that style being built, that generally replaced and threw far into the shade the earlier and simple post form.

The towers of this latter form of old windmill were made of every conceivable or possible form and material. Straight or cylindrical; tapering or cone shaped; octagonal or multi-sided; even bottle shaped, like a mammoth milk bottle of the present time. Again, on open arches, as in two notable structures later referred to—anything to carry the overhead work, according to the fancy or purse or conditions governing the builder. Of brick or stone or wood; slate, shingle or thatch covered, in height these towers ranged from 25 to 100 feet. The largest ever built was at Great Yarmouth, England, 11 stories high, and over 100 feet, exclusive of the great vanes. The great Dutch grist mills were however, a close second in height, and with a base of some 35 feet and a top width of 16 feet were massive structures indeed. These tall structures were divided by various floor levels, the lower rooms thus formed containing the mill-stones or saw or other driven machinery, while the upper ones were used for living quarters or storage. The structure of the smaller post mills, however, being suspended on the centre posts, was never of stone or brick, but wholly of wood, and these rotating or movable buildings ranged in size from about 10 by 12 feet to 16 by 24 feet in the larger ones, and up to two stories in height.

At the top of the mills, of course, was located the wheel shaft and gearing, and to protect this from the weather there was always a covering or "mill head" or top, and these tops have taken a great variety of interesting forms, for no apparent particular reason, and yet often a fixed style, following some geographical location. For instance, in France the almost universal

or characteristic shape is that of a steep true cone; in Denmark, Sweden, etc., a Turk's head or turban type was the standard; also in England, on the great tower mills. Yet in Holland, on the

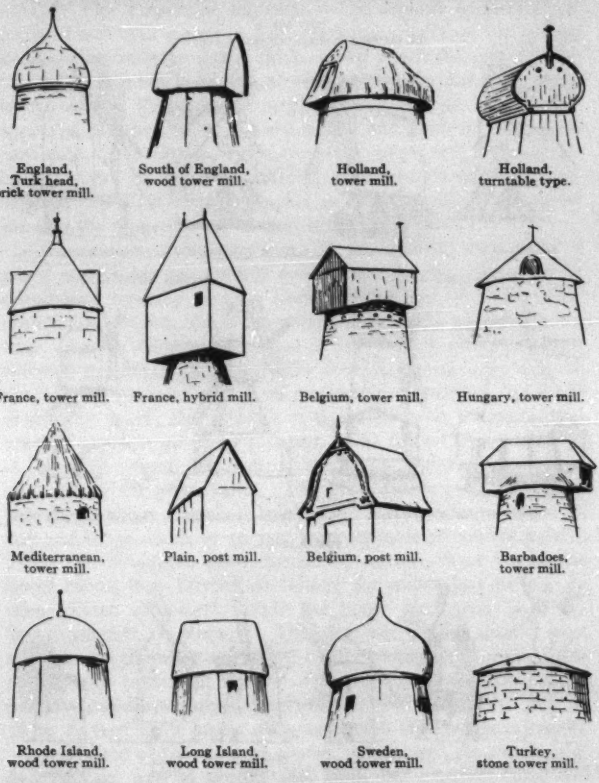


THE FOUR TYPES OF WINDMILLS.

same type of mill, such was never used, but a distinct Dutch form of irregular shape, and almost always thatched. And in the Mediterranean countries the tops become so flattened or

lowered as to in some cases almost disappear. The accompanying plate well illustrates these structural and geographical differences.

While the old mills all divide into either post or tower mills,

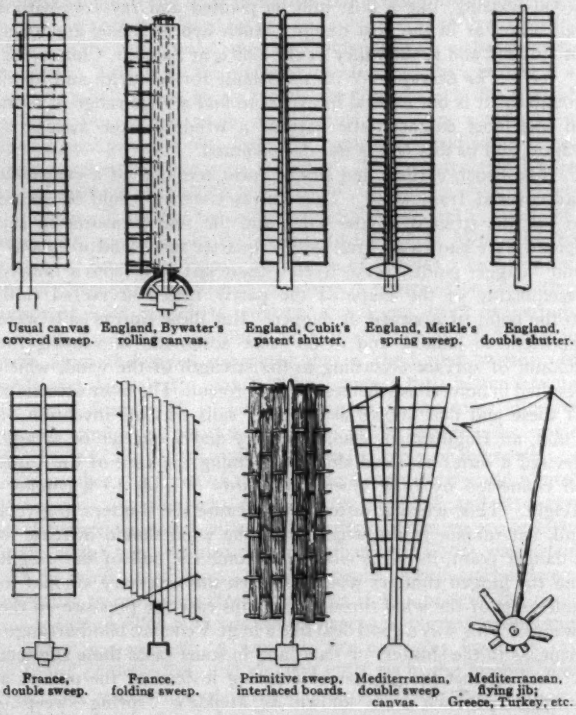


TYPICAL WINDMILL HEADS.

there are yet two well-defined further forms, or variations of type, that should be remarked.

Sometimes a tower mill would be constructed on a circular

timber framework or base, carried on rollers or iron balls, forming a large turntable, enabling the turning of the entire edifice to the wind, as need be, the same as a locomotive turntable or a rotary drawbridge is turned. This therefore parallels the post



TYPICAL WINDMILL ARMS.

mill type, in which the entire structure is turned to follow the wind, but turning on this turntable base instead of a post. This form was extensively used in the saw mill and lumber districts of Holland.

The other variation is what may be called a hybrid form—part post type, part tower type. In this the contained machinery is fixed in the base, and does not rotate, being thus of the tower mill design; while in the upper part of the mill a rectangular wood housing, like a post mill, is pivoted and revolves with a tail beam, as in the post design. Such hybrid forms are found in Holland and in the valley of the Loire, at Saumur, Chinon, etc.

(*B*) *The Sweeps.*—With mills built for centuries and by all countries, it is but natural to expect to find a wide range of form in this most characteristic part of a windmill—the sweeps or vanes; and in this one is not disappointed.

The usual, earliest and simple form was that of a canvas or sail covered framework. This canvas covering could be reefed to suit the strength of the wind, and the four measures of sail spread were known as "full sail," "quarter sail," "sword point" and "dagger point," respectively—these last two, from a fancied resemblance of the shape of the partly furled or reefed cloth to the point of a sword or dagger. But these canvas sails were laborious to handle, and in no sense automatic in varying the amount of surface according to the strength of the wind, which resulted in numerous schemes for betterment. The most successful of these and that known as "patent" sails was the invention of Cubit, an Englishman, who, a century and a quarter or so ago, devised a series of wood shutters forming the face of the vane, all connected by little levers and cords or rods to a counter-weight. This, when adjusted, would cause the shutters to give a full, flat surface to the wind, but if the wind should increase to a danger point, its force would overcome the pull of the weight and the hinged shutters would all open the necessary amount to spill some of the wind through and thus ease the pressure on the sweeps. This was a good deal like a huge Venetian blind arrangement, as to the shutters or slats; and in some cases these shutters worked against the tension of a spring instead of the pull of a weight, and such were known as Meikle's "spring sweeps." Still another arrangement—Bywater's—was that of the canvas being mounted upon a long roller, a good deal like a modern window shade, which rolled and unrolled as needed; but this was rather complicated and not much in vogue.

It was usual to have four-fifths of the area of the sweeps on one side of the arm and one-fifth on the other, and these were

"single sweeps"; while those in which there was a wide area on both sides—as almost the universal practice in France—were known as "double sweeps." Wood has been used as a sweep covering as well as canvas—as for instance in France, where one finds some of the most primitive, crude mills, with sails made of thin boards interlaced or woven into the vane framework; while, on the other hand, one also finds quite an elaborate construction. This is in the mills of the Loire valley, in which a dozen parallel boards on each vane are rigged much like a great Japanese fan, which when open presents a large surface, but when closed presents but little, the boards or wood strips overlapping and resting one upon the other. This construction I have found nowhere but in that section.

Going still further toward the primitive, we find in the Mediterranean, especially in the eastern end, in Asia Minor, in the vicinity of Smyrna, Turkey; the islands of Rhodes, Chios, Samos, and of Greece and the Sea of Marmora, a construction consisting simply of poles, anywhere from six to a dozen, stuck in the hub, carrying flying jibs, resulting in a wheel not far different in form from the paper spinwheel that a child may make! In Sicily and the Balearic islands these become a little better, having the wood framework to hold the canvas in the most effective position, and they form a transition phase between the crude jib wheels of the Orient and the elaborated types of the north.

In number the arms of the usual mill were four—and almost universally, for this was not only the simplest and strongest construction compared with the difficulty of framing six or eight firmly at the hub, but also the most effective. For it was found that the wind had to have a certain amount of exit space between the vanes to get away freely, and that if this part of the circle was too much filled with additional sweeps no corresponding gain in power was secured. A few very fine examples, however, can be found of these five- and six-arm mills, as in the famous 100-foot brick tower mill of Whitby, England, with five arms and its Turk's head top; and at Lewes, where a fine turret mill and others have five and six arms.

The length of these arms in an ordinary size mill was about 30 feet, giving a diameter to the wheel of 60 feet; but in the big tower mills referred to the arms were sometimes 50 and 60 feet long, making the wheels well over 100 feet in diameter. The

usual speed was about 16 revolutions a minute. If faster than 20 a danger point was reached that was very real, for there have been many cases of runaway mills, resulting from defective brakes or accident or carelessness; in which accidents millers have been caught in the vanes or sweeps and carried around and around and thrown off; or millstones bursting from too high speed have amputated the miller's legs; or friction heat has set the structure afire.

It is of course obvious that the surface of these windmill sails could not be really flat, as in that case the wind blowing against it would merely recoil and exert no power effect. A warp or twist was requisite, that the wind might give a thrust to the sail in passing through the wheel, precisely the reverse action of a screw propeller on a boat.

This twist was known as the "angle of weather" or "bosom," and the precise amount and form were the subjects of many early abstruse and learned studies. Practice finally settled down to an angle of about 17° at the inner end and about 8° at the outer end of the sail as being the most effective.

The mounting of these huge wheels was a matter of some moment, requiring very heavy construction, and this resulted in the use, as a rule, in all the earlier and medium size mills of a great shaft or log, turned or hewed octagonal, carried by gudgeon bearings, on old blocks of soapstone, or greased oak, or cast iron bearings at either end. Into the outer projecting end, outside the roof, the square ends of the vane shafts or sweeps were mortised and bound with straps and bolts of iron. Later and in the larger mills, and after foundry work was more available, these "great-shafts" were made of iron, giving much better bearings and enabling the sweeps to be bolted into square openings more conveniently. But with all these mills, especially the early simpler forms, there was an enormous loss in dead weight moved and in friction, and it is doubtful whether in most of them 50 per cent. of the force of the wind reached the mill stones below for useful work.

There was a popular belief that the wind came down from the heavens above, and that therefore the wheel should "look up" a little, to best meet it; with the result that the shaft of the mill was virtually never set level, as one might suppose, but always with the outer end a little higher than the inner, which angle of

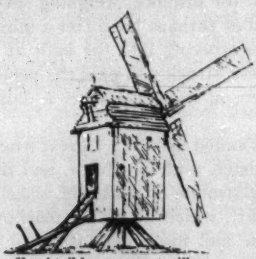
uplift varied from 5° to 10°. A very practical result of this was also gotten, in the necessary clearance of the tapering tower by the revolving vanes. For these revolving vanes were something to be respected—a 60-foot wheel, for instance, weighing several tons and having a periphery speed of perhaps 3000 feet a minute, and more than one horse or cow straying into the path of the arms in a mill in operation has been struck and paid the penalty. To guard against that, mills were at times set upon a dais or raised foundation, or fenced in.

The great shaft would have mounted upon it a "great wheel," from 8 to 12 or 15 feet in diameter, with cog teeth, and these engaged in a pinion or lantern or trundle or wallower wheel, as variously styled, on a vertical shaft, which led to the machinery below, and there, by any suitable and usual gear work of the olden times, whatever grist, saw, grinding, stamping or other machinery was to be driven would be duly operated by the wind power from above.

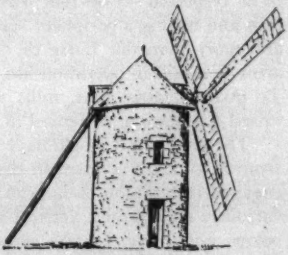
(*C*) *The Tail Beam or Vane.*—The third essential feature of these old mills was the device for keeping the wheel head-on to the wind, for the purpose of securing the fullest amount of power. And this was quite a point, in view of the perpetual shifting of the wind.

The first arrangement was that of a long beam or pole projecting from the rear of the old-time post mill, used precisely like a rudder. When the direction of the wind changed this would be pushed from one side to the other, to steer the post mill structure, pivoted on the post, again into the wind. And in the succeeding tower mills, where only the top or head would be turned, the tail beam principle was continued—as best developed in Holland, where a somewhat elaborately braced and several-membered framework was carried down to a point where it could be reached and moved as the wind shifted. But in Holland the mills became of large size and the weight to be moved was great, so that the old Dutch miller would blow a whistle to summon his hands for help. In later years they made use of a further rig of chains and tackle and a wheel like a pilot's, which enabled the snubbing around of the vanes and cap to be done far more easily than by pushing by hand alone. This old tail beam is, however, characteristic of the old-time small mill, and many are the tracks, well worn and circular, around the mill that betoken the

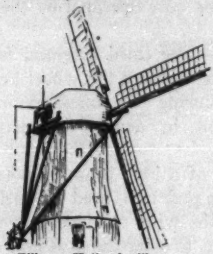
years of labor of the miller, even if eased by an old cartwheel to carry the end of the beam, as instanced in the well-known old mill at Nantucket and elsewhere.



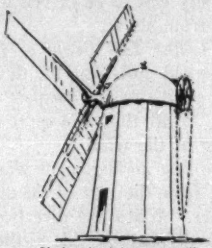
Usual tail beam on post mills and hybrid mills.



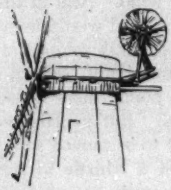
Tail beam. France, tower mill.



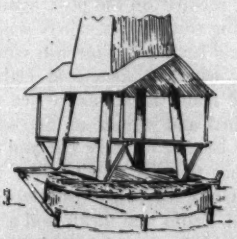
Tiller on Holland mill.



Chain-wheel on tower mill.



Cubit's automatic tail wheel, England.



Turntable mill, rollers and snubbing posts.

WINDMILL TAIL BEAMS OR TURNING GEAR.
For keeping mill-head on the wind.

Probably the next device for turning to the wind was the use of a chain pull, connected to overhead gear wheels and a cogged

track; for not only is this found in some early mills of Holland, and in the mills at Newport, R. I., but also in the rare old Peyto mill at Leamington, England, of 1632, of which I shall speak further. These chain pulls were either inside or out; the former being more protected from the weather.

But all these hand devices were completely eclipsed by another invention of Cubit—he of the "patent" sweep-shutter—known as Cubit's tail vane. This was the use of a small wheel of from 4 to 10 vanes, usually 6, placed in the rear of the head

Thatched tower pumping mill. Holland.

of the mill, up aloft, and so connected by a train of small gearing that when it rotated it would turn the main head a little, and if need be follow up the variations of the wind. So accurately was this designed that it is said that even with the wind shifting but a couple of degrees around the horizon the tail wheel would then begin to turn, and with its gearing would in turn wind the mill head, carrying the sweeps, into the wind. This automatic arrangement was almost universally adopted in England, in the better class of mills; yet, with the stolidity of the Dutch temperament, apparently content to continue with hand labor as did their grand-

fathers, this admirable device was rarely transplanted even to a place as nearby as Holland.

Turning now from the mechanical side of these old mills, as above, it is interesting to note the varied forms, uses and characteristics as found in the diverse parts of the world, and in the variety of races where and by whom these old home-made motors have been used.

Holland is usually taken as the home of the windmill, but that is so only in the greater proportionate number there in use than elsewhere. It is not true as regards origin nor the best

Saw-mill; turntable type. Holland.

development of them. It is a country notably flat, without water power, on the sea coast, and requiring great pumping equipment for draining, etc. This early resulted in the great number of windmills there found and associated with that little kingdom. It is said that in early days there were 10,000 of them. The greater number of them were used for lifting water to drain the "polders," or meadows or lowlands, through the medium of a scoop wheel or Archimedes screw. Some of them can yet be seen and in use, with fat Dutch babies apparently ever on the edge of falling in the sluiceways, yet never doing so. Nearly all of

these mills have been replaced by great steam-driven government pumping stations. For sawing wood, also, great numbers are yet used in the Zaandam district, where several hundred can be seen almost adjacent, a vista and forest of windmills. And in the heart of the chief cities one yet sees, here and there, an old-time brick tower mill, probably 200 years old—a family heritage,

"Petmolen" or small pumping mill. Holland.

with its clean and trim curtained little Dutch windows, its individual name, as of a ship, such as "The Admiral" or "The Parrot," over the door, and its old coat of arms and carvings and touches of color. For the Dutchman is fond of his substantial woodwork, and of his bits of color; and such finds expression in his mills, where carving like the stern of an old galley and color stripings of all the rainbow are both tucked in and flagrantly added.

The characteristic of the Dutch mill is, however, that of a thatch covering, both on sides and top, on the usual size common mill—something not found in any other country. It is said of them that there is also a code worked out—sort of a wigwag or semaphore system—so that by the position of the vanes as left when shutting down, the long-distance observer can read whether a carpenter is needed or a baby has been born, etc., etc. Certain

Brick tower mill; largest built. Great Yarmouth, England. (With Cubit's tail vane.)

it is that the mills make fine elevations for flag-flying on holiday occasions, for then the staunch colors of Holland will be found on the flagpoles atop the most of them. In noting the Dutch mills, one cannot overlook—nor wants to—the picturesque little "petmolens" or "jaskers"—diminutive post pumping mills, for small fields only—that, with long, slender vanes, seen through the haze or afar, almost suggest one of the old rocs from Sinbad the Sailor, caught in the act of alighting.

England, while numerically far inferior to Holland, is yet far in advance from the viewpoint of the fullest engineering development of this world's motor, as may be gathered from what has been said above as to the automatic shutters, tail vanes, etc. The largest, the most varied and the most efficient are found there. Many fine examples of these mills can be seen, a few of which are still in operation. In the south of England there are

Tower grist mill. South of England.

plenty of old wood structures of all forms—of which the turret is perhaps the most locally characteristic. This is a huge, or at least large size, post mill, often for some fine estate, with the base enclosed with a circular low or one-story building, used for storage, so that the external effect suggests a turret. In central England a good number of the tall brick tower mills yet stand.

For picturesqueness, however, no country surpasses old France. There the mills are small; the huge, towering struc-

ture of the Dutch and English is unknown. But one can find many of great antiquity, great variety of form and of great charm. The type seems to be the true cylindrical tower—not tapering—with the cone top. In the racetrack at Longchamps, near Paris, is an instance, while on the golf course at St. Lunaire, overlooking the sea coast, on the Channel, as in innumerable other places in the northern part of France, these little sentries

Turret post-mill. South of England.

of the past can be found. Picturesque as they are, however, they are not yet as much so as even an older and cruder form suggesting an old blockhouse. For above the stone first story is an overhanging wood second story, as so well instanced at St. Briac. And in the Loire valley are the very unique hybrid mills with the folding boards vane arrangement, already referred to, which at Saumur date back to 1682, as doubtless do the others of that not-to-be-found-elsewhere form.

Of old post mills of the usual wood form France has plenty, of which the one on top of Montmartre, in the Moulin de la Galette grounds, is perhaps the most prominent. It is one of the two or three remaining that were part of a dozen or more that crowned that hill in the early days, as shown in several views of old Paris. What changes it has seen in its 600 years of accredited age! In its timbers are shot and balls of the revolutions of 1814

Tower mill and tail beam. St. Lunaire, France.

and 1871. Within are the old bells and bunks and shrines of the generations of millers who operated it, one of whom is said to have been killed and quartered and hung on the four arms of his own mill by the successful assailants. In the same premises is a dear little miniature mill, which, with diminutive stones of but 18 or 20 inches in diameter, was used for grinding spices, in place of the usual grain for bread.

In Belgium we find, in the main, the post and tower mills of

Holland and the Netherlands; while in Germany, as well, the similarity to the Dutch mills is the only or chief characteristic. In Denmark and Sweden and in Iceland are the usual mills of this section, excepting that their octagonal, typical squatty grist mill nearly always has the Turk's head top instead of the irregular shape of Holland and Germany. And so pronounced is that that in Lawrence, Kan., where a mill was erected in 1858, with

Tower mill; double sweeps. St. Briac, France.

a Swedish top, inquiry develops that it was by Swedish emigrants. Iceland can claim probably the most northern mill ever erected, for in Reykiavik, a little isolated town of about 3000 inhabitants, we find an old mill, probably the first and only motor in the early days in Iceland.

There is greater picturesqueness—but, as usual, accompanied with less efficiency—in the southern part of Enrope, as, for instance, in Spain. Here, aside from the jib flying mills of the

Hybrid type of grist mill, 1682. Saumur, France.

Crude forms of tower grist mills; vicinity of Buda-Pesth, Hungary.

Mediterranean, we find primitive construction, crude devices and even the clay water bottles, or jars, bound to a cumbrous wheel, slowly turning over by wind power, for lifting water for irrigation, similar to devices seen on the banks of the Nile—although there operated by oxen. And in Spain we tread the country where the ever immortal Don Quixote, despite the adjurations

Mid-European type of post mill. Belgium.

of the faithful Sancho Panzo, charged at full speed a flock of windmills on the plains of Montiel.

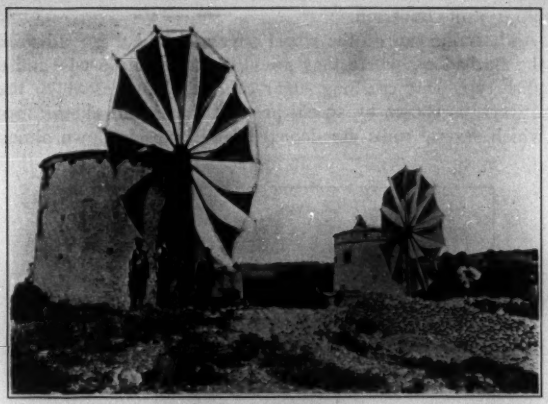
The crude structures of Greece and Turkey, already mentioned, are so crude that often no device is provided for turning to the wind, but, on the contrary, four mills are sometimes built in a field, facing, respectively, north, south, east and west; so that whichever way the wind comes some power can be secured. It is, however, more likely that prevailing winds are so constant

from one quarter there is but little use for a turning device, resulting in its omission.

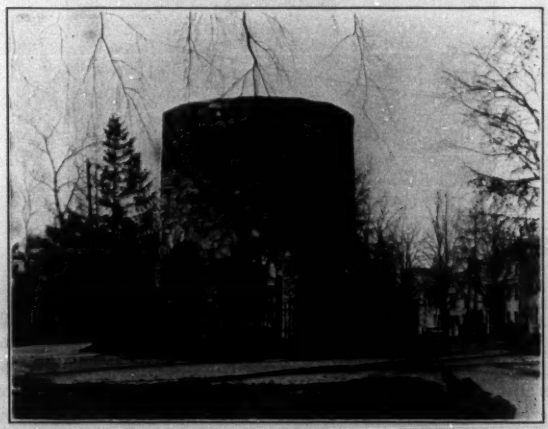
And so one can go the world over and find these old mills; to the Barbadoes, where they are still extensively used—and of English type—for crushing sugar cane; to Jamaica, where they once were, as shown by an old print of the earthquake of 1792, in which several mills are depicted bodily upside down almost,

Tower mill. Trapani, Sicily.

as would be a child's toy; to Peru, where over 13,000 feet above sea level in the Potosi silver mining districts of past times—centuries past—old prints show mills of the manifest Spanish type operating stamps for crushing silver ore; to the St. Lawrence, where the early settlers, both French and English, left their imprint in the shape of old mills on several promontories and points; to southern Illinois, where the German emigrants of the



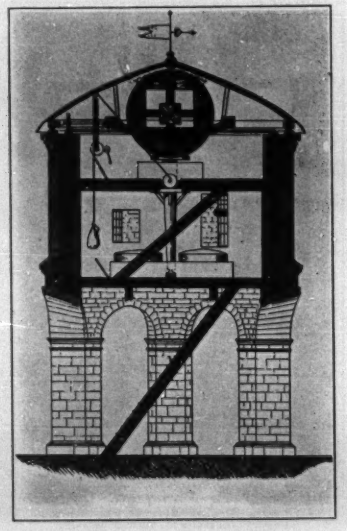
Multi-jib tower mill. Samos, Turkey in Asia.



Tower of the old Newport mill, of 1675, as now standing. Truro Park, Newport, R. I.

1820's and '30's brought with them the mills of the Fatherland, etc. In all quarters of the globe the world's chief motor for eight centuries can still be found.

And in closing this review of old windmills there is no instance to which reference should be made of quite as much interest as the old mill at Newport, known to every American antiquary and which, some two or three generations ago, was

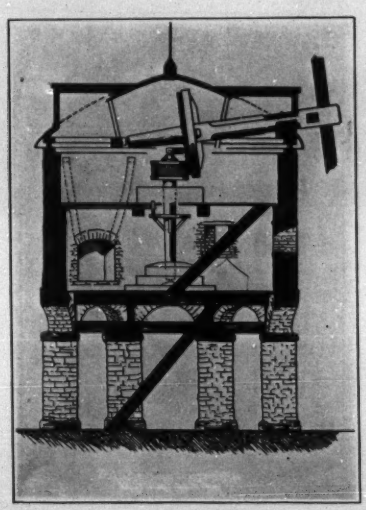


Chesterton mill, vertical section between columns.

ingeniously ascribed to the Norse in the period of 1100 or thereabouts. This theory, while highly picturesque, was unfortunate chiefly in never having anything except surmise to back it up. Not a jot nor tittle of record or physical remains could be developed to substantiate it, and it has long since been practically dropped by most students of American history. And when the following, that has in recent years been developed, is borne in

mind, there seems no vestige of reason left in the Norse theory. There is no question as to the following facts in relation to the Newport mill, and I speak with confidence, having in person surveyed and thoroughly investigated both it and its English prototype, as described:

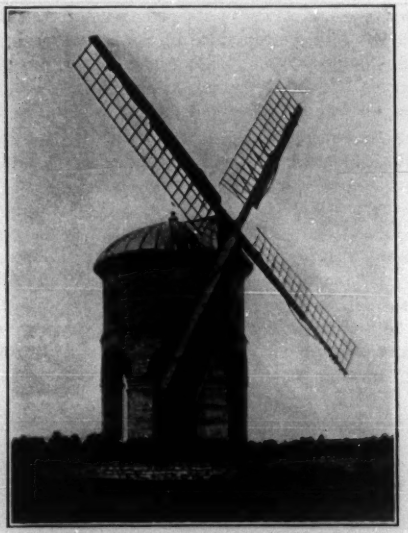
In 1675 Governor Benedict Arnold (the grandfather of the traitor) was in charge of the then early colony of Rhode Island.



Newport mill restored, vertical section.

Sixty years before he had been born in the Warwickshire section, England, in which the Peyto estate was perhaps the greatest and finest. On that estate there was completed the most elaborate windmill ever built. Inigo Jones, England's great architect of that time, designed it, and it was unique in its open arch design, its finely chiselled stonework and unusual adornment. Young Arnold was a lad of 17 at that time, and the building of this beautiful and remarkable windmill, in 1632, was, with small

doubt, a marked episode in his life and knowledge. Forty odd years later, he, by the chance of fate, was the Governor of the Rhode Island Colony. With the destruction of a previous wood windmill of 1665, blown down in a great storm, it became his duty to provide another one for the use of the little colony. And there is small doubt, indeed, that in doing that he undertook

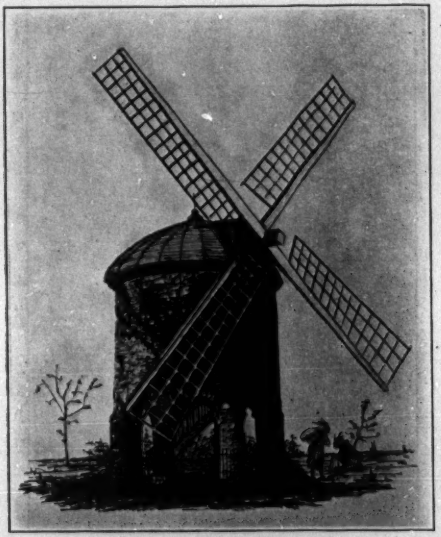


Inigo Jones-Peyto mill of 1632. Chesterton, Warwickshire, England.

to provide a mill that should be as nearly as possible a copy of the old mill at Chesterton, near Leamington—the best mill of which he knew. And so, without the measurements as to the general arrangement, size and design, from memory only, he there built, with the most limited facilities, a virtual replica of the Leamington-Peyto-Jones mill. In order to secure greater

permanence and protection against Indian attacks the mill was built of stone instead of wood.

For, while of course the fine stone work and carving and detail are missing, in this colonial condition, the general dimensions, the design and the interior arrangements are in substance the same throughout. It needs only the comparison of the plans of the two—side by side—to be satisfied as to that. Governor



Newport, R. I., mill as "restored" or probably constructed.

Arnold's birthplace and connection afford the reason of the similarity, and his will even speaks of "my stone built windmill." This old structure, still standing—as to its walls—in Truro Park, Newport, R. I., is perhaps America's greatest colonial relic, and with its prototype of Chesterton constitutes the most unique pair of windmills, having the greatest historic interest, of any attaching to our country's windmill history.

A NEW THEORY OF PLATE SPRINGS.

BY

DAVID LANDAU and PERCY H. PARR.

PAPER 3.

OUR second paper dealt comprehensively with the general relations between the various plates, their deflections, and the permissible external loads, for all plate springs, and also considered in detail numerous different types of leaf "points," sufficient in variety to cover all of the ordinary commercial springs in use at the present time. This third and, for the present, concluding paper will deal with two of the most important of the remaining questions. These are: first, the "nip" stresses, and, second, the "life" of the plates under the varying stresses produced in the metal when in use.

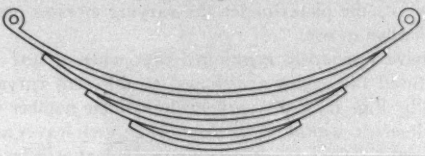
We have previously mentioned that when a leaf spring is manufactured the leaves are shaped to different curvatures, as indicated by Fig. 32, and this regardless of the number of leaves, their thicknesses, widths, etc. Now, when such leaves are assembled to form a spring, it is patent that each leaf will be deflected, more or less, in either a positive or a negative—down or up—direction, with the result that there is produced an "internal" stress in each of the leaves comprising the spring. The clear distance between any one plate and the next, measured at the centre, when the plates are placed in contact at the ends, but without pressure, is termed the "nipping distance," or the "nip," and the stresses produced by clamping or bolting up the plates so as to contact at the centre are called "nip stresses." The term "nip" is of English origin, the American spring-maker's shop phraseology being "pull" or "tension"; we ourselves prefer and shall use the English term as being the more expressive.

It will shortly be shown that the nip stresses, acting in conjunction with the stresses produced by the external loads, are of vital importance, for it is the combination of the two stresses, produced by the nip and external load, or the static and dynamic stresses properly combined which determines the life or endurance of each plate in a spring.

The study of the nipping stresses has been almost wholly

neglected by nearly every writer who has contributed to the study of the leaf spring, and we have never seen any paper in which the real utility and sometimes even the necessity of nip was pointed out. The existence of the nip stress has been mentioned by Prof. Perry in his "Applied Mechanics," where he says that to overcome the effects of "this objectionable practice the shorter plates should be made thinner." Of course this would reduce the nip stresses, but cannot wholly remove them; neither is it always desirable to do so. Paul Brennier, in his excellent memoir, "Etude sur les Ressorts."[1] has recognized the evil effects produced by these internal stresses, but we are reasonably assured that no writer had studied the question in connection with the strength and life of a spring until the advent of the year 1908,[2] when one of the writers suggested and applied the endurance

FIG. 32.



test to plate springs. The authors take the opportunity here afforded to state that most of the test results mentioned in the present paper were undertaken and carried out in the laboratories of the Sheldon Axle and Spring Co., of Wilkes-Barre, Pa., during the years 1911 to 1916. They are under deep obligations to this company and especially to their vice-president, Mr. Geo. M. Wall, for the many facilities he has afforded them to carry on this work.

At first sight it would appear that the practice of introducing any nip into plate springs is most objectionable; the further consideration of the conditions involved, especially in the operation of automobiles, shows that the nipping of the plates during the manufacture is not only desirable but sometimes absolutely necessary. In the case of springs which are never unloaded, the nip is not required, and is certainly undesirable if present in any

[1] *Bulletin de La Soc. d'Industrie Minerale*, April, 1912, to April, 1913.

[2] See article by J. E. Bishop in the *Australasian Coach Builder and Wheelwright*, entitled, "Springs," appearing in the issue of March 15, 1906, to January 15, 1908.

appreciable amount. For example, in railroad springs, where the vehicles run on a smooth metal track, the nip introduced during manufacture is very slight indeed, being no more than is required to insure that the plates contact properly. On the other hand, for automobiles and motor trucks, it is found, both theoretically and practically, that nip is not only desirable but is in fact a necessity. We shall show in due course that the nipping of the plates increases the endurance of the upper plates in most cases and particularly that of the very important master leaf, which is one of the advantages of introducing the internal or nip stresses. Of course, the reduction of the probability of breakage of the main leaf is only obtained at the expense of the other leaves, but they are comparatively of less importance; their breakage does not put the vehicle out of commission as in case of the main leaf breakage; the short plates are much more readily replaced, so that on the whole the advantage gained is considerable.

There is another point of practical importance, namely, that after encountering a sharp obstruction, as often occurs on an ordinary road, the wheels of an automobile frequently leave the road for quite an appreciable time; in such a case the springs may be and often are completely unloaded, even passing quite beyond the unloaded position on the "rebound." Now, if there were no nip in the springs, then, as soon as they reached the free position, the plates would separate, and in coming together again they would "chatter," making an objectionable noise. This fact is well known. One other point—if there were no nip, then, as soon as the spring reached the free position, there would be nothing but the stiffness of the master leaf to take care of the rebound, while with a spring which has been made with nip, the lower plates have an effect in increasing the stiffness of the whole spring for some little distance beyond the free position.[8]

We will now consider the intensity of the internal stresses produced by the introduction of the nip during the manufacture of the springs, and it will be found that the previous work given in our first, and especially that in our second paper, will greatly simplify the study of the question.

[8] See paper entitled. "Influence Affecting the Fundamental Deflection of Leaf Springs," by David Landau, in the Transactions of the Society of Automobile Engineers, 1914; also a paper entitled, "Apropos des Contre Ressorts," by A. Contet, *La Techn. Auto et Aerien*, July 15 and August 15, 1912.

For the calculations of the nipping reactions and stresses our experience has shown that it is best to consider a spring as being built up by the addition of successive plates, commencing with the shortest. Thus, we shall first consider the reaction or pressure resulting from the clamping up into contact of the shortest plate with the adjacent short one or the second short plate; then we will consider the reaction resulting from the clamping of the third short plate *to the two-plate clamped partial-spring first obtained;* and a similar reasoning is then to be continued for all of the plates until the spring is complete.

For the analysis indicated we will let N_n be the distance between the nth and the $n+1$th plates when they are in contact at the ends without pressure—that is to say the nip distance—and let nip $(1 \ldots n) - n+1$ be the nip distance between the partial spring of n plates and the free $n+1$th plate.

Now, on referring to the second paper, page 709, it will be seen that on adding the second shortest plate to the shortest one, or Plate No. 2 to Plate No. 1, and clamping up to contact at the centre we must then have

$$Y_1 + y_2 = N_1, \text{ or } (B_1 + A_2)\, W_1 = N_1$$

so that the nip pressure between the two plates will be

$$P_1 = \frac{N_1}{B_1 + A_2}$$

we use P for the nip pressure or nip reactions in order to obviate any confusion between the reactions produced by the nips and those produced by the external loads; they are of a similar nature, and they act at the same places, but it has been found advisable to use a different symbol for each so as to avoid the possibility of confusion in identification. The symbol P_n as here used may be defined as the nip pressure or reaction produced when the nth plate is added to the $n-1$ plate partial (clamped) spring.

Next, for the nipping reaction between the third plate and the two-plate clamped spring, we must note that the nipping distance will not be N_2, which is the nipping distance only when all the plates are free; the dimension N_2 will have been modified by the deflection of the second short plate produced by clamping it to the shortest plate. Again referring to our second paper, it will be seen that the upward deflection of the second plate, due to its being clamped to the shortest one, will be $P_1 A_4$, and therefore the total nipping distance when the third plate is to be added

to the two-plate spring will be $N_2 + P_1 A_4$, and it follows that

$$N_2 + P_1 A_4 = y_2 + Y_2$$
$$= A_2 P_2 + B_2 P_2$$

from which there is obtained

$$P_2 = \frac{N_2 + P_1 A_4}{A_2 + B_2}$$

and similarly, for the nip $(1 \ldots n) - n + 1$, the nipping distance will be $N_n + A_{4n-4} P_{n-1}$ and we shall have

$$N_n + A_{4n-4} P_{n-1} = (A_{4n-1} + B_n) P_n$$

from which

$$P_n = \frac{N_n + A_{4n-4} P_{n-1}}{A_{4n-1} + B_n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (55)$$

and the successive use of this equation (55), with gradually increasing values for n, will determine the internal reactions produced by the nips.

It must be noted that for each step equation (55) gives the value of the nip reaction between the $n+1$th plate and the n-plate clamped spring, when the $n+1$th plate is added; this reaction can be considered in the nature of an external load on the n-plate spring, and therefore the internal reactions between the lower plates will be increased in the same manner as if an external load of the same amount was applied to the partial spring. For example, when the third plate is added to the two-plate clamped spring, the nip reaction between the short and the next plate will be increased by an amount equal to $N_2 W_1 / W_2$, or to $N_2 C_1$. The nipping reaction for each additional plate affects all of the lower plates in a similar manner, and the calculations should therefore be carried out in the manner shown by the following example, which is the front spring of the United States Government's Liberty B standardized truck.

This is a ten-plate spring in which the plates have the half-lengths of 5, 7⅛, 9¼, 11⅜, 13½, 15½, 17½, 19½, 21½ and 21½ inches respectively for the short end. The long end is one inch longer overall, and the lengths of the other plates are all practically in the proportion of 22½, to 21½ to the lengths mentioned. The lower eight plates are all 3″ × 5/16″ and the two plates forming the " compound " top plate are each 3″ × ⅜″. The nip distances, when the plates are in contact without pressure are, measuring from the short plate upwards, 1/32, 1/32, 1/16, 1/16, 1/8, 3/16, 5/16, 7/16, and 7/16 inches respectively (these figures were taken from *one* only of the actual springs).

The calculated reactions W for the external load are 1.000, 1.221, 1.296, 1.327, 1.341, 1.363, 1.376, 1.385 and 1.363 respectively. The calculated stiffness, taking E as 29×10^6, is 1057 lbs. per inch deflection. The test loads of an actual spring were 1070 lbs. at 1" deflection, 1565 lbs. at 1½", 2070 lbs. at 2", 2580 lbs. at 2½", and 3100 lbs. at 3", which agree within the limitations of practice with the calculated stiffness.

The fundamental constants for this spring, obtained as indicated in our second paper, are found to be as follows:

n	A_n	B_n	C_n	W_n
1	.0002149	.0002149	.8187	1.000
2	.....	.0003337	.9419	1.221
3	.0002149	.0005124	.9768	1.296
4	.0003518	.0007434	.9895	1.327
5	.0006217	.001024	.9840	1.341
6	.0003518	.001315	.9901	1.363
7	.0006217	.001648	.9935	1.376
8	.0008999	.002031	.9062	1.385
9	.001360	.002203	.7442	1.528
10	.0008999	.001785		1.861
11	.001360			
12	.001829			
13	.002530			
14	.001829			
15	.002530			
16	.003239			
17	.004229			
18	.003239			
19	.004229			
20	.005169			
21	.006401			
22	.005169			
23	.006401			
24	.007640			
25	.009212			
26	.007640			
27	.009212			
28	.01079			
29	.01275			
30	.01079			
31	.007291			
32	.008448			
33	.009859			
34	.008448			

In the above table it will be noticed that values for C_n are given for both 8 and 9 as the value of n. When dealing simply with the reactions due to the external load, the top compound plate is considered as a single plate with a moment of inertia equal to the sum of the moments of inertia of the separate plates, as has been mentioned previously, but when we are dealing with the nipping reactions, it is necessary to consider every plate separately; that is, as in the present case, we must consider the partial spring obtained by adding the 9th plate to the 8-plate partial spring, and also consider the complete spring obtained by adding the 10th plate to the 9-plate partial spring. As the 9th and 10th plates are of the same length, then for calculations concerning the external load they need be considered as only one plate, but, as indicated above, for the nipping reactions they have to be taken separately as in the previous table.

The nipping reactions may now be tabulated as follows:

n	N_n	P_n	P_n (total)
1	.031	7	420
2	.031	35	505
3	.062	50	499
4	.062	47	460
5	.125	53	417
6	.187	60	370
7	.312	71	313
8	.437	129	244
9	.437	127	127

In the preceding table, the P's are of course those calculated by the successive application of equation (55). The P's (total) are determined thus: P_9, or the reaction produced on adding the 10th plate to the 9-plate partial spring, is equal to 127 lbs.; the relation between a l 1 on the end of the 9-plate partial spring and the reaction between the 9th plate and the 8-plate partial spring is $W_8/W_9 = C_8 = .9062$ and $127 \times .9062 = 115$. Adding this to the nipping reaction of 129 lbs. produced when adding the 8th plate to the 7-plate partial spring, the total nipping reaction between the 8th and the 7th plates will be 244, as given in the table. Similarly, the total nipping reaction between the 7th and the 6th plates is $244 \times .9935 + 71 = 313$ lbs. A continuation of the same process determines all of the nipping reactions, as given in the table above under P_n (total).

We may here note that these nip calculations determine the amount of the camber to be given to the master leaf in forming. In the case under discussion it is seen that the final total nipping load on the master leaf or 10th plate is 127 lbs. and the deflection produced by this load is $127 \times .009859 = 1.25''$, and therefore the master leaf must be formed with a camber $1\frac{1}{4}''$ less than the desired camber for the assembled spring; this was actually the case for the spring measured.

We may now say that, in the absence of the theory as developed in the previous papers, the present study of nip and nip deflection would not have been possible, but that with the application of this theory very many results which have been observed in practice may now be accounted for. Other results of practical importance but, somewhat foreign to the present paper, have been predicted from the theory and have been confirmed in actual use.

ENDURANCE OF PLATE SPRINGS.

We now enter into the final stage of the present exposition, which is that of the "life" or "endurance" of the plates composing a spring under the stress variations experienced in actual service.

In the past the commercial value of a spring or its "strength" was usually measured by the static load it would support without taking a permanent set, or else, as was the practice of the French spring-makers—and amongst them, the most renowned of all, the Etablissements Lemoine of Paris, France—by the elastic elongation of the material. It was believed formerly, due to the teachings of Mons. Lemoine, and is still perhaps held to be the case by some engineers, that the greater the elastic elongation or the higher the elastic limit of the material, the greater is the "strength," and also as a result the endurance or life of a spring. We have found, however, that this condition does not necessarily hold, and at least it is certain that there is no linear relation between the elastic limit of the material and the life of a spring.

It is a well-known and accepted fact in applied mechanics that any piece of material will withstand a considerable number of applications of a load (within the elastic limit) provided the said load does not produce stresses varying in sign from positive to negative—tension to compression—and that when the load pro-

duces stresses varying in sign, then the material subjected to such alternating stresses breaks down more rapidly. For instance, as a practical illustration, if we have a piece of metal bar and wish to break it by hand without exerting any great force we bend it back and forth, so as alternately to produce positive and negative stresses, and this procedure rapidly breaks the bar, even with a ductile metal which will bend double on itself—lead, for instance.

The stresses in the plates of a plate spring due to the nip are not of the same sign in all of the plates, and the amount of the stress, and in some cases its sign, will change when the external load is applied. In a spring composed of more than two plates we may find, under certain conditions of the loading, plates or parts of plates with zero stress—that is, the positive effect of the external load may exactly neutralize the negative effect of the nips; this is of great importance.

As a simple illustration, for a mental physical conception, we may take, say the two-plate spring shown in Fig. 5. When these two plates are bolted together at the centre, the master leaf is deflected *upwards*, or negatively; the short plate, on the other hand, is deflected *downwards* or positively (in the same direction as it is deflected by the external load) and hence there is a negative stress produced in the master leaf and a positive stress produced in the short leaf during the manufacture—all before any external load is placed on the completed spring.

Suppose we now deflect this spring positively, as by placing an external load on it, then both leaves move in the positive direction and when the master leaf has been deflected a distance equal to the initial negative deflection due to the nipping load, it will have (at certain places) zero stress, while at the corresponding deflection the stress in the short plate is positive and is equal to the sum of the nipping stress and the load stress. The total stresses and the stress variations are quite different for the two plates; the range of stress in each is determined by the external load and is the same as if the nip had not been introduced, but the total or maximum stress and, more particularly, the life depends both on the nip and on the external load.

The life of any leaf in a spring evidently depends both on the maximum stress to which it is submitted and on the "range" or the stress variation. From the theory, as developed above, we

can calculate with accuracy both of these factors, and so in a similar manner we ought to be able to predict the life of each and every plate. It is the custom (at present) to consider the life of the spring, as a whole, to be that of the shortest life of any of the plates of which it is composed. The ideal spring would be the one in which all of the plates except the master plate had the same life, while for practical considerations the master plate had a life slightly in excess of the others. This last condition should prevail because the master leaf is the most important, it being the one which is directly connected to the vehicle. So long as the master leaf exists intact then the vehicle may run quite a distance with care and at slow speed, whereas if the master plate was fractured the car could not be run at all. (See Landau, United States Patent No. 1,199,013, issued September 19, 1916.)

ENDURANCE OF MATERIALS UNDER VARYING STRESS.

The question of the endurance of materials under fluctuating stress is of considerable practical and theoretical importance, but unfortunately up to the present time there has never been any satisfactory solution correlating the endurance and stress range relation; we have studied much of the available information, both old and new, without finding anything that will give a very definite answer to the question for our needs, which is, to predict the life when the stress variations are known. We have tried many of the existing formulæ and have carefully compared the results as given by them with the results obtained on the endurance testing machines, and as the result of our study we have found that for present purposes and, with the present state of our knowledge, the parabolic relation of Gerber, based on a study of Wöhler's tests on materials subjected to varying stresses, gives an answer more nearly in accordance with the observed facts than any of the other formulæ. Gerber's formula, however, does not succeed in giving the relative life of the various plates; it does appear to be able to predict with reasonable accuracy which of the plates will break the first—the curve of relative liability to breakage for the various plates composing a spring as given by the use of Gerber's relation is quite similar to that obtained by plotting the results of destruction tests on more than 500 springs —but the actual numerical relations are, however, still considerably in error. In the absence of more accurate information and with

the present state of our knowledge we shall, for the time being, make use of the Gerber relation.

Gerber's formula is [4]

$$F = \frac{R}{2} + \sqrt{f^2 - nRf} \quad \ldots\ldots (56)$$

in which

F = the maximum stress intensity
R = the range of stress
f = the ultimate static strength of the material, and
n = a constant to be determined from practice, = about 2 for hard steels.

The form in which this equation is given is not convenient for our purpose, and we have found it better to write

$$R = aF$$

where

$$a = \frac{\text{maximum stress} - \text{minimum stress}}{\text{maximum stress}}$$

we may then write

$$F = \frac{2f\left(\sqrt{n^2a^2 + (2-a)^2} - na\right)}{(2-a)^2} \quad \ldots\ldots (57)$$

$$= \text{say } bf,$$

where b is a function of a and n (= 2) only.

The limits for a are evidently zero and 2, corresponding to static loads and to reversed loads of equal amounts respectively. For $a = 2$, equation (57) fails to give a direct answer, as it leads to the indeterminate form 0/0, but by referring to the original equation (56) it is at once seen that for this case $b = \frac{1}{2n}$, or $\frac{1}{4}$ for the hard steels.

In order to facilitate the application of this theory to plate springs, Table VIII has been calculated, giving the values of b corresponding to values of a varying by 0.02 for the complete range from 0 to 2.

We will now apply this to the Liberty B front spring. The nipping loads and the relations between the reactions and the external loads have already been given. The external load for which the spring was designed is 2000 lbs. With reference to the values of I and Z (the moment of inertia and the modulus for bending); the plates have rounded edges and are slightly concave, so that the values of I and Z are slightly less than they

[4] See Unwin, "Elements of Machine Design." Vol. 1, Chapter II.

would be for rectangular plates.[5] A careful calculation shows that for the $3'' \times 5/16''$ plates $I = .006687$ and $Z = .04280$, while for the $3'' \times 3/8''$ plates $I = .01169$ and $Z = .06236$.

Making use of these figures, it will be found that the stresses and stress ranges for the different plates composing the spring are as follows:

n	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*
1	1133	491	642	.56	.679	1358	1.20	1.44
2	825	350	475	.58	.666	1332	1.62	1.07
3	660	238	422	.64	.635	1270	1.93	90
4	543	144	399	.74	.584	1168	2.15	.80
5	480	93	387	.80	.555	1110	2.31	.75
6	414	25	389	.94	.496	992	2.40	.72
7	320	−60	380	1.18	.412	824	2.58	.67
8	209	−168	377	1.80	.278	556	2.67	.65
9	249	−325	574	1.76	.284	568	1.75	.99
10	136	−438	574	1.30	.378	756	1.73	1.00

In the above table the column *n* is the number of the plate under consideration, counting from the shortest plate, which is called No. 1.

Column I is the stress due to both the nipping and the external loads in thousands of pounds per square inch.

Column II is the stress in thousands of pounds per square inch due to the nipping loads only.

Column III is the range of stress or the difference between *Column I* and *Column II* again in thousands of pounds per square inch.

Column IV is *a*, or the range of stress (*Column III*) divided by the maximum stress (*Column I* or *II* as the case may be).

Column V is *b*, as found from Table VIII for the corresponding value of *a*.

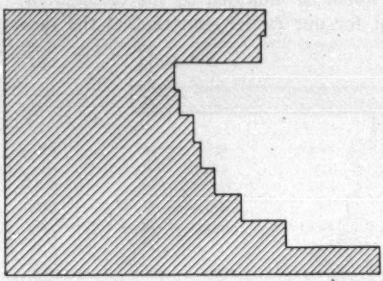
Column VI is the useful working stress (ultimate) as determined by multiplying the ultimate strength of the material, assumed to be 200,000 lbs. per square inch, by the corresponding *b* of *Column V*.

[5] We would draw attention to the fact that nearly all actual spring steel bars are rolled slightly concave in the thickness and with rounded edges, so that the moment of inertia *I* and the strength modulus *Z* are less than for a rectangular bar. The reduction is greater than is usually appreciated, being in the neighborhood of 10 per cent. on an average, and reaching 14 per cent. with some sections; for accurate results it is therefore necessary to use the true values of *I* and *Z* in our formulæ, and not to consider the section as rectangular, which may lead to very serious errors.

Column VII is the factor of safety, as determined by dividing the figures of *Column VI* by those of *I* or *II*, whichever may happen to be the greater.

Column VIII is the relative liability to fracture of the various plates, being proportional to the reciprocals of *Column VII*, according to the Gerber expression before mentioned. These are the most interesting since they give the relative probabilities of the breakage of the various plates when the liability of breakage of the master leaf is taken as unity.

FIG. 33.



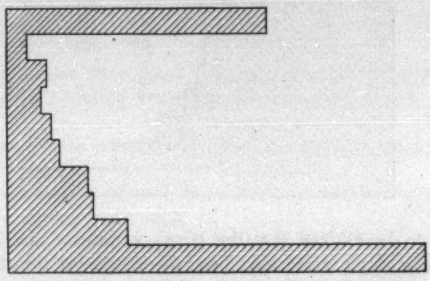
It is to be noticed that the stress variations and breakage liabilities as given above have been calculated for the case when the external load is alternately fully applied and completely removed. In actual operation the load fluctuation is usually from something under to something over the normal, with an occasional total removal, and even reversal, on the rebound after the wheels of the vehicle have encountered an obstacle: The relative lives of the different plates will be found to be different, according to the particular load variation adopted as the basis of calculation, but, on the whole, it will be similar to that obtained by taking the load variation as being from zero to full load alternately, and in the absence of absolute information as to the actual average variation we have made the calculations of the basis mentioned.

The results of the calculation are shown by Fig. 33, from which the relative liability to breakage is more readily appreciated than it is from looking at the table given above. It is seen that the short plate is by far the most likely to fracture, and

also that there is a considerable liability for the master and the long plates to break. This is quite in accordance with the results of observations of other springs both on the endurance testing machines and in service.

Fig. 34 shows the average relative liability to breakage for the various plates of plate springs, as determined by a careful study of more than five hundred fractures. It will at once be noticed that the general form of the calculated liabilities as shown by Fig. 33 is quite similar to the observed liabilities as shown by Fig. 34, but that the middle plates do not, in practice, break with such frequency as would be indicated by the calculations. This is the justification for our earlier remark that the theory appears to

FIG. 34.



give a fair idea as to which plate will break first and some idea of the relative liability, but that it does not give the relative liability to fracture with any great degree of accuracy. In the present state of knowledge regarding the effects of alternating stress on materials, this appears to be as far as it is possible to go; later on, when the question of alternating stresses has been further advanced by investigations now under way by others, we may expect to be able to predict with absolute certainty the relative liabilities to fracture of the various plates and to design springs which will be perhaps theoretically and practically perfect; in the meantime, we can say that our New Theory of Plate Springs is as perfect as present-day knowledge permits—especially that portion of it which deals with the question: "How long will any spring endure?" This phase of the problem is only an extension

of the general reasoning of our New Theory of Plate Springs which the second paper has so carefully expounded.

TABLE VIII.

Max.–min. / max.	Factor	Max.–min. / max.	Factor	Max.–min. / max.	Factor
.00	1.000	.70	.604	1.40	.353
.02	.990	.72	.594	1.42	.348
.04	.980	.74	.584	1.44	.343
.06	.969	.76	.574	1.46	.339
.08	.958	.78	.564	1.48	.335
.10	.948	.80	.555	1.50	.331
.12	.937	.82	.546	1.52	.327
.14	.926	.84	.537	1.54	.323
.16	.914	.86	.529	1.56	.319
.18	.902	.88	.520	1.58	.315
.20	.891	.90	.512	1.60	.311
.22	.879	.92	.504	1.62	.307
.24	.868	.94	.496	1.64	.303
.26	.856	.96	.488	1.66	.299
.28	.844	.98	.480	1.68	.296
.30	.832	1.00	.472	1.70	.293
.32	.821	1.02	.465	1.72	.290
.34	.809	1.04	.458	1.74	.287
.36	.797	1.06	.451	1.76	.284
.38	.784	1.08	.444	1.78	.281
.40	.772	1.10	.437	1.80	.278
.42	.760	1.12	.431	1.82	.275
.44	.749	1.14	.424	1.84	.272
.46	.737	1.15	.418	1.86	.269
.48	.725	1.18	.412	1.88	.266
.50	.714	1.20	.406	1.90	.263
.52	.703	1.22	.400	1.92	.260
.54	.691	1.24	.394	1.94	.257
.56	.679	1.26	.388	1.96	.254
.58	.666	1.28	.383	1.98	.252
.60	.656	1.30	.378	2.00	.250
.62	.646	1.40	.373		
.64	.635	1.42	.368		
.66	.625	1.44	.363		
.68	.614	1.46	3.58		

The Phenomena of Fluorescence. DESMOND GEOGHEGAN. (*Chemical News*, vol. 117, No. 3058, p. 322, October 11, 1918.)—Fluorescence was the name given by Stokes to designate certain phenomena which he observed when following up the investigations in the same subject of Herschel and Brewster. Stokes noticed that under certain conditions the rays of light are capable of undergoing a change of refrangibility. Herschel and Brewster had observed that some varieties of calcium fluoride (fluorspar), and also certain other substances when in solution, appeared colorless when looked at by transmitted light, but when viewed by reflected light presented an appearance which varied with the material used, being of a bluish color in some solutions and of a greenish color in others. Stokes found that this property, which as before stated he called fluorescence (on account of its having been first observed in fluorspar), is characteristic of a large number of substances other than fluorspar; thus if by means of a lens of long focus, preferably made of quartz, a line of the sun's rays be focussed on a solution of quinine sulphate, rendered more soluble by the addition of two drops of strong sulphuric acid, contained in a glass trough, a beautiful cerulean blue cone of light is formed which is much brighter on the surface and whose intensity rapidly diminishes as it penetrates the liquid.

It thus appears that fluorescence is due or is caused by the rendering visible to the eye of the ultra-violet rays. During the process of the invisible ultra-violet rays becoming visible, certain rays of the spectrum are necessarily absorbed. Thus rays of light which have passed through a sufficient thickness of a fluorescent substance lose thereby the power of exciting fluorescence when they are passed through a second layer of the same substance.

Power Requirements for Domestic Electrical Appliances. ANON. (*Motor Age*, vol. 34, No. 25, p. 9, December 19, 1918.)—The current needed by the usual devices is perfectly definite—and is given in the following table:

	Watts	Equal to
Fifty-candlepower lamps	40	2 lights
Water pump, 1/4 hp.	200	10 lights
Water pump, 1/2 hp.	600	30 lights
Air pump, 1/2 hp.	600	30 lights
Cream separator, 1/4 hp.	200	10 lights
Churn, 1/4 hp.	200	10 lights
Electric water heater	350	18 lights
Electric grill	500	25 lights
Electric stove	600	30 lights
Vacuum cleaner	160	8 lights
Washing machine	200	10 lights
Flat iron	600	30 lights
Electric toaster	525	26 lights
Fireless cooker	600	30 lights
Electric fan	75	4 lights
Warming pan	75	4 lights

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A RELATION CONNECTING THE DERIVATIVES OF PHYSICAL QUANTITIES.[1]

By Mayo Dyer Hersey.

[ABSTRACT.]

IN this paper it is shown how the theory of dimensions may be used in a differential form; a procedure which appears fruitful particularly in investigating the effect of given sources of error on the performance of measuring instruments.

The examples which led to the necessity for developing this method are discussed at the end of the paper and illustrated by experimental data.

NEW BAUMÉ SCALE FOR SUGAR SOLUTIONS.[2]

By Frederick Bates and H. W. Bearce.

[ABSTRACT.]

MANY different Baumé Scales have been proposed and used in the past. At the present time there are still in use in the United States three different scales for liquids heavier than water. Two of these, namely the "Holland" scale and the "Gerlach" scale are used in sugar work. Neither is adapted to modern requirements. The new table lies between the "Holland" and "Gerlach" scales and has three important advantages which should commend it for general use. They are:

1. It is based upon the specific gravity values of Plato, which are considered the most reliable of any available.

2. It is based on 20° C., the most convenient and widely accepted temperature for sugar work.

3. It is based on the modulus 145, which has already been adopted by the Manufacturing Chemists' Association of the United States, by the Bureau of Standards and by all American manufacturers of hydrometers.

* Communicated by the Director.

[1] Scientific Papers of the Bureau of Standards No. 331.

[2] Technologic Paper, No. 115.

SOLDERS FOR ALUMINUM.[3]

[ABSTRACT.]

THE use, serviceability, method of application and composition of solders for aluminum are discussed in the light both of special tests made at the Bureau on commercial and other compositions of solders and of general experience with them. All soldered joints are subject to rapid corrosion and disintegration and are not recommended except where protection from corrosion is provided. Suitable compositions for solders are obtained by the use of tin with addition of zinc or both zinc and aluminum within wide percentage limits.

A CRITICAL STUDY OF THE LEDEBUR METHOD FOR DETERMINING OXYGEN IN IRON AND STEEL.[4]

By J. R. Cain and E. Pettijohn.

[ABSTRACT.]

ERRORS in the method and their remedies are discussed. Special methods for preparing samples are given and new forms of apparatus are described. The metallurgical significance of the results obtained by the Ledebur Method is pointed out. It is shown that "(*a*) The Ledebur method requires extraordinary precautions to obtain reliable results. The errors we have described undoubtedly affect in greater or less degree nearly all results by this method that have been described in the literature, and if these are approximately correct it is because of compensation errors; (*b*) The Ledebur Method as described determines with certainty only oxide of iron, oxides of manganese above Mn, and the oxides of nickel, copper, and tungsten if the latter three ever exist in steel. In turn such oxides are determined correctly only in case they exist in the metal uncombined as silicates which probably seldom happens; (*c*) Ledebur oxygen determinations show no distinguishing features for acid Bessemer, basis or acid open-hearth, duplex, electric furnace or crucible steel; (*d*) Ledebur oxygen determinations show no differences in steels deoxidized with a variety of deoxidizers."

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[3] Bureau of Standards Circular No. 78.
[4] Technologic Papers, No. 118.

TESTS FOR HOLLOW BUILDING TILES.[1]

By Bernard D. Hathcock and Edward Skillman.

[ABSTRACT.]

Introduction.—Originally hollow building tile was used mostly for its fire-resisting properties, but, as its other advantages have become more generally recognized, its range of usefulness has been greatly broadened until to-day it is an important structural material. And, as a consequence of the rapid growth of its use and the relative lack of definite and reliable information of its strength, these tests have been made by the Bureau of Standards.

Tiles are molded of clays which are quite diversified in their properties, and, after drying, are burned in downdraft kilns at a temperature well beyond initial vitrification of the clay, but rarely high enough to complete vitrification. These methods introduce variables, especially of color and porosity, which are of great importance because of their relation to the strength properties of the tiles, and have been given consideration in the classification of the tiles of these tests. It is a well-known fact that in a downdraft kiln the upper courses of the tiles are heated to a higher temperature than the lower ones. This gives the top tile a higher degree of burning, those near mid-height a medium degree of burning, those near the bottom a low degree of burning. In general, the high burned tiles are dark in color, the medium burned of medium shade, and the low burned light. However, this is not always true, for the natural color of some clays or the presence of coloring matter will cause a variation.

Scope of the Tests.—The tests of this paper are limited to those of compression and absorption. The total number of those performed is approximately 250, of which the majority were upon tiles in compression. Stress-strain readings were taken upon 114 of these for modulus of elasticity determinations. About 70 absorption tests were made upon samples taken from tiles previously tested in compression. All the tiles were graded according to their color, as dark, medium, or light corresponding to the variations produced as described above. The tiles tested were made with few exceptions from clay of the buff burning variety, and the colors given indicate variations in the buff color.

Method of Tests.—Previous to testing the tiles, their sectional

[1] Technologic Papers No. 120.

areas and weights were determined. The former was done by measuring the walls and partitions with calipers and computing the sectional area from these measurements. Then they were capped with plaster of Paris to insure a uniform bearing in the testing machine. Small brass plugs were also set in some of the tiles for compressometer readings. The type of compressometer used was the 8-inch Berry strain guage, and readings were taken with it near the four corners of every tile upon which stress-strain relations were desired. The testing machines used were of the Olsen universal type.

The absorption tests were made upon three samples selected from each tile upon which the absorption determination was desired. The tiles from which these samples were taken had been previously tested in compression.

Results.—The results of the compression tests with moduli determinations show that the strain produced by loading a tile is approximately a linear function of the applied load until failure is approached, or in other words, the modulus of elasticity of a tile is practically constant until failure. This indicates also that there is no definite proportional limit for tile; that is, the proportional limit is coincident with failure.

Tiles were tested on end, on edge and flat, and the results show that in general a tile develops both the greatest unit strength and greatest total strength when it is laid on end. The relation between the moduli of elasticity of tiles and their compressive strengths is somewhat variable, or the tile having the highest modulus of elasticity may not have the greatest strength, but in general if the modulus is high, it is to be expected that the compressive strength will also be relatively high.

There was found to be no definite relation between the loads at the incipient failure and the maximum loads sustained by the tiles. In some cases the incipient failure occurred early in the tests, but in other tests no notice of failure was observed until the maximum loads were reached.

There is shown to be a relationship existing between the colors of the tiles and their compressive strengths and the moduli of elasticity. The dark and medium burned tiles have about the same relative compressive strengths and moduli of elasticity, while the same properties of light burned tiles are on an average much lower.

From the results of the absorption tests it was found that the maximum compressive strengths vary approximately inversely with the percentages of absorption. Also the percentages of absorption of the tiles vary with their colors. In general, the darker the tiles the lower the percentages of absorption are likely to be, but this is not always true because either the material or the artificial color of the tiles may often be deceptive in this respect.

THE TABLE OF UNIT DISPLACEMENT OF COMMODITIES.[6]

By Harry M. Roeser and Lillie E. Johnson.

[ABSTRACT.]

THIS circular showing (1) the number of pounds per cubic foot as packed for shipment, (2) the number of cubic feet of space required for a short ton, (3) the number of cubic feet of space required for a long ton, and (4) the manner in which the material is packed, lists several hundred commercial commodities alphabetically. Appendixes give special information concerning automobiles, canned fruits and vegetables, and fresh fruits and vegetables.

This table has been prepared to meet an immediate demand for such information and will be revised and augmented from time to time as further data is obtained. The Bureau will, therefore, be pleased to receive information, criticism, and suggestions from those interested in the table.

ELECTRICAL OSCILLATIONS IN ANTENNÆ AND INDUCTANCE COILS.[7]

By John M. Miller.

[ABSTRACT.]

THE mathematical theory of circuits having uniformly distributed electrical characteristics such as cables, telephone lines and transmission lines is applied to the oscillations in antennæ and inductance coils.

It is shown how the frequency of the natural oscillations of an antenna may be determined analytically or graphically when inductance coils or condensers are inserted in the lead-in. Expres-

[6] Circular No. 77.
[7] Scientific Papers No. 326.

sions are derived which permit the calculation of the effective resistance, inductance and capacity of the antenna, and it is shown that in so far as frequency or wave length computations are concerned the simple formula applicable to ordinary circuits with lumped constants gives very accurate results. Experimental methods are given for determining the effective and static or low frequency values of the antenna constants.

Inductance coils are likewise treated from the standpoint of the theory of distributed characteristics. Expressions are obtained for the reactance of the coil at any frequency and for the natural oscillations of a circuit of coil and condenser. It is further shown that, in so far as the frequency of oscillation is concerned, an inductance coil with distributed characteristics is equivalent to a pure inductance of constant value with a constant capacity across its terminals. Excepting for skin effect, this pure inductance would be the same as the low frequency inductance of the coil. This explains a fact which has been frequently observed experimentally, in particular for single layer solenoids.

TOLUOL RECOVERY.[1]

By R. S. McBride, C. E. Reinicker, and W. A. Dunkley.

THE importance of high explosives in the present war has been amply demonstrated. Nearly all types of explosives are used in some way, but trinitrotoluol, commonly known as T.N.T., because of its high power and great stability, is one of the preferred explosives. As an important constituent in shells T.N.T. is used both alone and mixed with other explosives. Especially for naval use it is used alone, because the greater stability permits longer storage of the shells before use. On account of the great demand for T.N.T. there has grown up also a large demand for those materials from which it is made, especially toluol. This material finds numerous applications in the chemical industries, but particularly it has been used in the manufacture of dye-stuffs and for the preparation of T.N.T. For this latter it is only necessary to treat the toluol with nitric acid under proper conditions in order to produce the explosive, which is then refined by appropriate means to such degree of purity as is required for the use for which it is intended.

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[1] Technologic Papers No. 117.

THE COMPRESSIVE STRENGTH OF LARGE BRICK PIERS.[1]

By J. G. Bragg.

[ABSTRACT.]

THE following is an abstract of the report on tests of large brick piers which were made at the Pittsburgh laboratory of the Bureau of Standards in coöperation with the National Brick Manufacturers Association.

The purpose of this investigation was to determine the strength developed by brick piers of normal size as used in modern buildings, using in their construction such materials and grades of workmanship as are available in the United States.

The variables considered in the investigation are: (1) the quality of bricks employed with respect to grade and geographical location; (2) the quality and kind of mortar; (3) the grade of workmanship employed, and (4) the bonding of courses or method of laying the bricks.

The investigation comprises tests on forty-six piers 30″ × 30″ × 10′ in height, also four piers of the same cross sectional dimensions 5′ in height. The bricks used in their construction are representative of four widely separated districts east of the Mississippi River and are classified according to the following three grades:

Grade 1. Hard burned or best quality.
Grade 2. Medium burned or considered as common.
Grade 3. Soft burned or poorest product marketed.

Three mortars were used in the beginning and three grades of bond and workmanship were employed throughout the investigation.

The mortars used were:

1. 1 part cement, 3 parts sand by weight.
2. 1 part lime, 6 parts sand by weight.
3. 1 part { 15 per cent. lime / 85 per cent. cement }, 3 parts sand by weight.

The different methods of bonding are as follows:

1. Alternating header and stretcher courses.
2. Header course every 4th course.
3. Header course every 7th course.

[1] Technologic Papers No. 111.

Wire mesh was used in two of the 8-foot piers to study the effect of lateral reinforcing in the horizontal joints. A more than usual number of tests of individual bricks were made in order to determine the relation of the strength of single bricks to the compressive strength of piers.

Results.—The first indication of failure observed was the same in all cases and appeared in the form of small hair sized cracks in the individual bricks. The cracks widened and extended to other courses under additional load, finally becoming confluent and extending almost the entire length of the pier. Soon thereafter final failure occurred accompanied by a spawling off of the outer ring of bricks. Very little crushing of the bricks was apparent after failure except in the case of the softer bricks laid in cement or cement-lime mortars. The cause of incipient failure of the piers is attributed to a transverse failure of the individual bricks.

The tests show that variations in the number of header courses used does not effect the ultimate compressive strength of the pier. Failure of the individual bricks by fluxure would render the header courses ineffective by such time as they would be useful in preventing an outward bulging of the masonry.

The quality of bricks is shown to be a very important factor in its effect on the compressive strength of the pier. The compressive strength of half bricks flat and one edge, also the transverse strength or moduli of rupture of the bricks are shown to be proportional to the compressive strength of the piers.

Very little difference in strength is apparent in piers of 1:3 Portland cement and sand mortar and those of 1 (15 per cent. lime and 85 per cent. cement) :3 sand mortar. In the last named mortar 35 per cent. by volume of the cement is replaced by lime. These piers of cement and cement-lime mortars, however, developed strengths 50 per cent. to 75 per cent. higher than those of pure lime mortar. There is a considerable advantage in the easier working qualities of the cement-lime mortar over the pure Portland cement mortar. In consideration of the results of these and previous tests on piers of smaller cross sectional dimensions, from 25 per cent. to 50 per cent. of the cement in a 1:3 cement mortar may be replaced by hydrated lime without appreciably affecting the compressive strength of the masonry; the higher percentage to be used in piers of small cross sectional dimensions.

A study of these and previous tests indicate that lateral reinforcing in the horizontal joints is effective only when placed in every joint.

The following empirical formulas are given for use in computing the strength of brick piers:

1. $P = K p$
2. $P = K R$ where

P = the ultimate unit compressive strength of the pier,
p = the unit compressive strength of single half bricks,
R = the unit transverse strength or modulus of rupture of single bricks,
K = is a constant depending upon the kind of mortar used.

The values of K are given as follows for the mortars used in this investigation:

	Mortar	Values to be determined by tests of single Bricks		Value of K
1	15 per cent. lime, 85 per cent. cement, to 3 parts sand by weight.	Unit compressive strength flat	$= P$	.26
		Unit compressive strength on edge	$= p$	.30
		Modulus of rupture from transverse test	$= R$	1.25
	1 part lime to 3 parts sand	Unit compressive strength flat	$= P$	.11
		Unit compressive strength on edge	$= p$	.14
		Modulus of rupture from transverse test	$= R$	.65
	1 part cement to 3 parts sand	Unit compressive strength flat	$= P$	.27
		Unit compressive strength on edge	$= p$	.32
		Modulus of rupture from transverse test	$= R$	1.45

The modulus of rupture is computed according to the formula:

$$R = \frac{3}{2} \frac{P l}{b d^2}$$ in which,

R = the modulus of rupture,
P = the breaking load, in pounds, of a single brick in a flatwise position supported at the ends and loaded at the centre.
l = the distance between the supports (in these tests 7 inches),
b = the breadth of specimen in inches,
d = the depth of specimen in inches.

The complete report includes twenty-four figures and numerous tables. There is also a chapter devoted to previous tests giving abstracts and tables of the results from previous investigations of the load bearing values of brick piers.

Industrial Alcohol. ANON. (*The* (London) *Times Engineering Supplement*, vol. 14, No. 529, p. 228, November, 1918.)—In Great Britain, at present, alcohol is mainly obtained by fermentation processes from grain together with small quantities by distillation of molasses. In Germany, production from potatoes by a combined hydrolytic and fermentation process has been largely used to supplement the grain fermentation process. The first stage in the operation consists in the conversion, by treatment with acids, of the starch content of the potato into glucose, which is then fermented to yield the alcohol desired. Among other possible sources, attention has been directed to the utilization of wood waste, and to the synthetic production of alcohol from calcium carbide.

The principal constituent of wood is the complex carbohydrate commonly known as cellulose, and this is available in abundant quantities in the wood waste obtained in the operations of the timber trade. The problem of recovering alcohol from such material consists in the conversion, by disintegration, of the cellulose constituent of the wood into fermentable sugars from which alcohol can be readily obtained. The possibility of effecting such a conversion has been known for more than a century, and many attempts at commercial realization of the project have been made. It is only recently, however, that success has become practicable, largely owing to detailed study of the problem by the lumber interests in North America stimulated by the assistance of Government investigation, such, for example, as that conducted by the United States Forest Products Laboratory at Madison, Wisconsin. As to yields obtained, 20 to 22 per cent. of the dry wood is fermentable sugar. This corresponds to 35 gallons of 95 per cent. spirit per ton of dry wood. Thus far, in actual practice, the yields have scarcely exceeded 20 gallons per ton, as contrasted with a yield of 80 gallons per ton from corn.

To a country such as Great Britain with no considerable timber areas, the synthetic process of alcohol manufacture must be of prime consideration. As developed hitherto, calcium carbide is the starting point of the synthesis, a fact which suggests the necessity of cheap power production. By treatment of the carbide with water, acetylene gas is obtained, and this on reaction in presence of a catalytic material is converted into acetaldehyde. From the latter, by a further process of catalytic reduction, alcohol results. The production of alcohol from acetaldehyde does not exhaust the possibilities of synthetic processes. Large scale production of ethylene hydro-carbons would lead to the development of a synthesis by direct hydration from which alcohol would result in a one-stage operation.

NOTES FROM NELA RESEARCH LABORATORY.*

THE INFLUENCE OF TEMPERATURE ON THE TRANSMISSION-FACTOR OF COLORED GLASSES.

By M. Luckiesh.

THERE are numerous gaps in our knowledge of the physics and chemistry of colored glasses which either have not been spanned at all or have been flimsily bridged by theory supported more or less by inadequate experimental data. On the other hand, a number of investigators have made excellent contributions which indicate that light may be shed on some of the questions by physical data of various kinds. Hyde, Cady, and Forsythe, in studying red pyrometer glasses, noted the influence of temperature on the transmission characteristic of a red glass and investigated this influence for temperatures of 20° C. and 80° C. The transmission-factor of the red glass is appreciably less for various wave-lengths at the higher temperature than at the lower temperature.

It appeared of interest to study this aspect with a number of commercial colored glasses and later to carry the work further with glasses especially made for the purpose. Only the transmission-factor for total visible radiation has been considered so far, but an idea of the change in spectral transmission may be gained by noting the change in color of the heated specimen. A given specimen was cut into two pieces and one was kept at room temperature, while the temperature of the other was increased gradually to 350° C. The relative transmission-factors of the two specimens were measured throughout this range, and a few of the results are presented in the table. No color-difference was encountered during the measurements except that due to a change in the spectral transmission characteristic of the heated specimen. This color-difference became very marked for specimens 5 and 10 at temperatures above 100° C. No analyses of the glasses have been made in this preliminary work. The color of the hot specimen is given as compared with that of the cold

* Communicated by the Director.

Specimen	Principal coloring element	Color		Relative transmission-factors at various temperatures (centigrade)				
		Cold	Hot	30°	100°	200°	300°	350°
1	Copper....	Medium red....	.....	100	97	92	87	84
2	Cobalt.....	Light blue.....	.....	100	101	104	107	108
3	Cobalt.....	Deep violet.....	Deep blue...	No appreciable change.				
4	Gold.....	Pink.....	Violet.....	100	99	96	94	93
5	Copper....	Blue-green.....	Yellow-green	100	98	94	87	82
6	Manganese.	Purple.....	Blue-violet...	100	97	94	91	90
7	.....	Lemon yellow...	Orange.....	100	94	84	75	71
8	.....	Dull yellow....	.....	100	98	94	91	90
9	Copper....	Deep red.....	.....	100	86	67	50	42
10	Chromium.	Yellowish green.	Yellow.....	100	95	84	72	67

specimen in each case where a change was appreciable. All the glasses, except the two containing cobalt, decreased in transmission-factor as the temperature increased. The curves obtained by plotting temperature and transmission-factor are approximately straight lines with the exception of that for specimen 5. Owing to the slow change in hue in the red end of the spectrum the red glasses, 1 and 5, did not change appreciably in color when heated, notwithstanding large decreases in their transmission-factors.

Aluminum Alloys. ANON. (*The Chemical Trade Journal and Chemical Engineer*, vol. 63, No. 1647, p. 446, December 14, 1918.)—Aluminum was merely a scientific curiosity a generation ago, the production in 1883 having been but 83 pounds; but it is now one of the most common metals in use, with an annual production of hundreds of thousands of tons. It is most important in its alloys, especially in those with magnesium and copper. The alloy known as magnalium is a series of mixtures containing 10 to 30 per cent. of magnesium; it is silver-white in appearance, strong, ductile, easily cast, takes a fine polish, and has a specific gravity of only 2 to 2.5, somewhat less than that of aluminum itself. With 10 per cent. of magnesium the melting-point is between 650° and 700° C. The metal is made harder, more brittle and finer in polish by additions of magnesium up to the practical limit of 30 per cent.; it may be given a dark color by maceration, or it may be nickelled or gilded. Duralumin, with 3.5 to 5.5 per cent. of copper and about 0.5 per cent. each of magnesium and manganese, has greater hardness, tensile strength and polish, and may be easily hardened, but it is given special value by its resistance to the action of sea water and dilute acids. It is a little heavier than aluminum, with a specific gravity of about 2.8. Other alloys, similar to magnalium, but adapted to special uses, contain small percentages of nickel, tin, lead and iron.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE RETICULATION OF GELATINE.[1]

By S. E. Sheppard and F. A. Elliott.

[ABSTRACT.]

THE production of reticulation is ascribed to localized release of normal, *i.e.*, lateral, swelling of the gelatine layer on plate or film. Normally the gelatine layer swells and shrinks almost entirely in the direction perpendicular to the support. If it is treated with reagents (or under conditions of temperature) so that an excessive swelling is produced, it may strip off the plate. If the excessive pressure is restrained by tanning agents, it may easily happen that the restraint is not uniform; that is, we do not have at every point exactly compensating amounts of the swelling substances and the tanning reagent, but accumulation of one at one point, and accumulation of the other at an adjacent point. In consequence, we get a localized excessive swelling and shrinkage adjacent to each other, the net result of which is the reticulation pattern. At the same time, if developed silver grains are present in the film, these aggregate in the more swollen portions, leaving the less swollen parts poorer in silver. It is pointed out that excessive "graininess" in developed images is very probably due to incipient or latent reticulation, because the products of development are tanning substances which will tend to be retained by the silver as reduced; photographs and curves illustrating these results are given.

* Communicated by the Director.

[1] Communication No. 71 from the Research Laboratory of the Eastman Kodak Company, published in *J. Ind. and Eng. Chem.*, Oct., 1918, p. 727; *Studio Light*, Sept., 1918, p. 8.

Domestic Fuel Saving. ANON. (*The* (London) *Times Engineering Supplement*, vol. 14, No. 529, p. 229, November, 1918.)—The problem of heating a house or room by the combustion of solid or gaseous fuel, without waste, is far more difficult of solution than that of heating water in a steam boiler or materials in a furnace, and whereas the thermal efficiency of industrial heating apparatus ranges from 50 to 70 per cent., the average efficiency of domestic heating appliances is probably less than half this figure. This large difference is due to the fact that, for heating rooms and houses in this country (England), radiant heat is chiefly utilized; and that the ordinary old-fashioned type of firegrate is a most inefficient apparatus for producing radiant heat, or even for obtaining proper combustion of all the constituents of the fuel. In England there is a rooted objection to any system of heating that produces "stuffiness," or hinders the free and rapid movement of air, and with all its defects, the British system of heating rooms provides excellent ventilation. It is this fact that has saved the old-fashioned type of firegrate from long ago having been discarded.

In regard to the combustion of fuel, the aim is to produce as much radiant heat as possible, and to reduce the losses of heat by convection and conduction to the lowest possible limit. A red glowing surface of coal or coke is one of the best of heat radiators, and a small bright fire is, therefore, much more efficient for heating a room than a much larger one that has been permitted to become dull and lifeless. Another objection to the latter is that, when fresh coal is added, the temperature is generally too low to ignite the volatile constituents of the coal; the larger portion of these gases, therefore, escape up the chimney unburnt, and not only contaminate the atmosphere with tarry vapors, but carry with them one-third of the calorific value of the fuel absolutely unused. To allow a fire to fall into this dead state and then add fresh fuel before reviving it, is most wasteful, although nine out of ten persons do not realize the fact. The most practical and scientific method of saving coal in the heating of rooms by open fire-grates is always to maintain a bright glowing fire, and to add fresh fuel a little at a time, but often enough to maintain the fire at the original size.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE COLOR LABORATORY OF THE BUREAU OF CHEMISTRY. A BRIEF STATEMENT OF ITS OBJECTS AND PROBLEMS.[1]

By H. D. Gibbs.

[ABSTRACT.]

ABOUT two years ago the color work of the Bureau of Chemistry, formerly confined to the solution of problems arising from the enforcement of the Food and Drugs Act, was organized and extended to include questions pertaining to the manufacture and utilization of colors. The new plan provided for laboratory investigation of natural and artificial colors, as well as for the reproduction of laboratory processes on a technical scale.

The aim of the laboratory studies, which so far naturally have predominated over the plant studies, has been to develop processes which can withstand competition, a goal best reached by investigating conditions underlying yields and costs. These studies may be divided into five classes: (1) *Processes,* such as chlorination, sulphonation, oxidation, and sublimation; (2) *dye intermediates,* comprising phthalic anhydride, H-acid, a large number of sulphonic-acid derivatives of naphthalene, benzene, toluene, and cymene, together with the chlorin compounds of toluene and cymene, and a number of the quinolines; (3) *dyes,* including malachite green, the sulphonephthaleine, cymene dyes, dyes for sensitizing gelatine emulsions of the silver halides, and several biological dyes; (4) *medicinals;* and (5) *analytical methods* for handling the products. Papers on the analytical methods devised have appeared in the *Journal of Industrial and Engineering Chemistry* (1918), vol. 10, pages 425, 436, and 453, in the *Journal of the American Chemical Society* (1918), vol. 40, pages 1443, 1449, and 1453, and in the *Journal of the Washington Academy of Sciences* (1918), vol. 8.

Several large-scale operations have also been attempted. In coöperation with various manufacturers, the development of a

* Communicated by the Chief of the Bureau.

[1] Published in *Jour. Ind. Eng. Chem.*, 10, 1918, p. 802.

process for the manufacture of phthalic anhydride has been studied. Plant investigations on the chlorination of toluene and the manufacture of various alcohols and acetone are now in progress.

As a result of the work done by the Color Laboratory, twelve patents have been dedicated to the people, and applications for a number of new patents are pending.

CERTAIN RELATIONS BETWEEN CRYSTALLINE FORM, CHEMICAL CONSTITUTION AND OPTICAL PROPERTIES IN ORGANIC COMPOUNDS.[1]

By Edgar T. Wherry.

IN previous work on the refractivity of crystalline substances the mean refractive index has usually been employed. It seemed, however, desirable to inquire into the possibility of correlating the several indices of a given substance with its crystal structure, instead of concealing in mean indices whatever relations may exist. The Lorentz-Lorenz expression, $\frac{n^2-1}{n^2+2} - \frac{M \times \rho}{W}$, is most satisfactory, and for short the left-hand term is referred to as the "refraction" and denoted by the letter R. If the refractive indices in different directions in a single anisotropic substance be substituted for n, directional values of R, called R_a, R_b, and R_c, will be obtained, the first two being identical in uniaxial crystals. The atomic weight (W) being always, and the refractivity (M) usually, the same throughout the several values of R must be proportional to those of the density (ρ), or factors corresponding to it, in the several directions. The ratio of the $R's$, which may be termed the "refraction ratio," should therefore give some information as to the structure of the substance. The phenomenon of dispersion of double refraction renders the refraction ratio variable with the wave-length of the light, but calculation in some typical cases shows that the variation rarely exceeds 3 units in the third decimal place over the visible spectrum, so this may be ignored.

The spacings between the planes passing through the centres

[1] Published in *Journal Washington Academy Sciences*, Vol. 8, pp. 277–285, and 319–327, May 4 and 19, 1918.

of gravity of the atoms in crystals are connected with the crystallographic axial ratios. The less the spacing of the planes in any direction in an anisotropic substance, the greater should be the refraction in that direction. If the layers are all close-packed, the factor ρ may be inversely proportional to the spacing d, and there should be an exact inverse relation between refraction ratio and crystallographic axial ratio, at least in cases where there are no serious disturbing factors. The work reported is limited to the tetragonal system. The crystallographic axial ratio usually adopted is not necessarily the one related to the optical properties, the alternate ratio or even the mean between the usual and the alternate being of significance in some cases.

In urea, $CO(NH_2)_2$, the axial ratio, c/a, is 0.833, and the refraction ratio, R_ω R_ε is 0.834, the inverse proportionality being exact. A possible space-lattice for the substance, worked out on this basis, is found to agree with a variety of data, in particular with the atomic diameters of the elements present. In pentaerythrite a similar relation exists, but the composition is so complicated that only a suggestion of the structure can be given. In mellite the facts are similar, provided that the alternate axial ratio is taken. The double propionate group, of the metals *Ca*, *Sr*, *Ba*, and *Pb*, also shows interesting relationships of the same type. Several exceptions are noted, in which no proportionality between the two kinds of ratios appears to exist, but it can be shown that there are disturbing factors, such as intense coloration and asymmetric carbon atoms, present, so that the general rule of inverse proportionality may be regarded as generally applicable. Preliminary results with crystals of other systems are announced.

AMERICAN SUMAC: A VALUABLE TANNING MATERIAL AND DYESTUFF.[1]

By F. P. Veitch and J. S. Rogers.

[ABSTRACT.]

SUMAC grows wild and abundantly on uncultivated lands in certain areas of North America, in quantities more than sufficient to tan all the light leather made in this country, if need be. At

[1] U. S. Department of Agriculture Bulletin 706.

present large amounts of sumac are allowed to remain ungathered each year, while vegetable tanning materials of similar nature are quite extensively imported. This native tanning and dyeing material should be more completely utilized, and also improved in quality to serve as a check on the rising cost of like tanning and dyeing materials, to lessen our dependence on foreign countries, and to give the country people in certain sections an additional source of employment. The important tannin bearing species of sumac indigenous to North America may be readily recognized.

Analyses of a large number of samples gave for the leaves and leaf stems the following average tannin content: Dwarf sumac (*Rhus copallina*), 28.95 per cent.; white sumac (*Rhus glabra*), 25.14 per cent.; staghorn sumac (*Rhus hirta*), 27.66 per cent. The tannin content of the stalks was found to be 7.77 per cent., 6.84 per cent., and 7.07 per cent., respectively.

An estimate by the Bureau of Chemistry gave a calculated yield from thick uniform stents of 4864 pounds green weight, or 1621 pounds cured, of sumac to the acre. In no case should an able-bodied man be satisfied with less than 200 pounds of cured sumac for his day's work. The total loss in weight of the mixed sumac leaf and stalks from gathering until it reaches the extract maker probably averages very close to 60 per cent. The extracted sumac has some value as a fertilizer for use on land deficient in organic matter.

Among the directions for proper gathering and curing are the following important points: Collect, preferably, only leaves and leaf stems; avoid red and yellow leaves; harvest from June to September, inclusive; do not unduly expose the gathered leaves to the sun; keep them from getting wet from rain or dew; do not pile the green sumac in layers over 1½ feet deep, and turn it frequently during drying to prevent heating and molding.

Properly gathered and cured domestic sumac leaves contain practically as much tannin as the imported Silician sumac, and will yield an extract much better in color and quality than that obtained from the domestic sumac as generally prepared at present for market. An appeal is made for coöperation between gatherers, dealers, and extract makers, with a view to producing not only more domestic sumac but also sumac of excellent quality.

THE FRANKLIN INSTITUTE.

(Proceedings of the Annual Meeting held Wednesday, January 15, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 15, 1919.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 2.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

The tellers of the election, Messrs. Jennings, Colvin, and Picolet, submitted the report of the ballots cast for President, Vice-President, Treasurer, and members of the Board of Managers, and the following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

Henry Howson, Vice-President (to serve three years).

Cyrus Borgner, Treasurer (to serve one year).

Francis T. Chambers, W. C. L. Eglin, Alfred C. Harrison, Nathan Hayward, Charles A. Hexamer, Robert W. Lesley, Marshall S. Morgan, and E. H. Sanborn, Managers (to serve three years).

The President presented a statement of the work of the Institute for the fiscal year ending September 30, 1918, with the reports of the various committees of the Institute and Board of Managers.

The paper of the evening was presented by A. Russell Bond, B.A., Managing Editor of the *Scientific American*, New York City, N. Y., entitled "Deep Sea Salvage After the War." An account was given of the damage done by the German undersea boats since August, 1914, it being estimated that about fifteen million tons of allied and neutral shipping had been sunk during the continuance of the war. Mention was made of the plans of Germany and the Allies in connection with the salvage work in deep water where ordinary methods would be ineffective. New apparatus devised by the Germans, as well as our own methods for recovering ships sunk in deep water, were described. The subject was illustrated by numerous lantern slides. Messrs. Eldridge, Henderson, the Secretary, and others participated in the brief discussion which followed the reading of the paper.

A vote of thanks was extended to the speaker for his interesting paper, and the thanks of the Institute were also conveyed to the tellers of the election for their services.

Adjourned.

GEORGE A. HOADLEY,
Acting Secretary.

MEMBERS OF THE FRANKLIN INSTITUTE WHO ARE IN THE ACTIVE MILITARY OR NAVAL SERVICE OF THE UNITED STATES GOVERNMENT.

Name and rank	Branch of service	Location
Allen, Henry B., Captain	Ordnance Dept., N. A.	France
Amram, Philip W., 2nd Lieut.	Student Army Training Corps	Harvard Univ.
Anderson, Geo. L., Colonel	Board of Ordnance & Fortification	Washington
Atherholt, Gordon Meade	Aeronautical Mechanical Engineer, Signal Corps	Washington
Atterbury, W. W., Brig. Gen.	Director-General of Railways	France
Bacon, Raymond Foss, Lt. Col.	Head of Chemical Service Section, U.S.N.A.	France
Barnhart, G. Edw.	Aeronautical Mechanical Engineer, Signal Corps	Fairfield, Ohio
Barr, John H., Major	Ordnance Reserve Corps	Washington
Barrett, C. D., Major	9th Engineers	
Bartow, Edward, Major	U.S.N.A. Sanitary Corps	France
Billings, A. W. K., Lieut. Com.	Chief Engineer, U. S Naval Forces (Aviation)	London
Booz, Horace Corey, Colonel	Railroad Transportation Corps, U.S.N.A.	France
Bostwick, John Vaughan, Capt.	O.R.C., 315th Infantry	
Breed, George, Lieutenant	Fleet Naval Reserve, U.S.N. R.F.	New York
Brown, Lucius P., Captain	Sanitary Corps, Division of Food and Nutrition	Camp Greenleaf
Bunting, C. M., Colonel	E.O.R.C., U.S.A.	France
Cadwalader, Governeur, Major	Ordnance Dept., U.S.R.	
Caldwell, E. W.	Medical Officers' Reserve Corps	
Capps, W. L., Rear Admiral	Chief Constructor, U.S.N., Bureau of Construction and Repair	Washington
Carty, John J., Colonel	Signal Corps, U.S.A.	
Cathcart, Wm. L., Lieut. Com.	U. S. N. R. F.	Washington
Chance, Edwin M., Major	Chemical Warfare Service, N. A.	Baltimore
Clark, Beauvais, Sergeant	108th Field Artillery	France
Clark, E. B., Major	Gas and Flame Service, A.E.F.	France
Clark, E. L., 1st Lieut.	Signal Corps, 401st Telegraph Battalion	Camp Devens
Clark, Theobald F., Capt.	Field Artillery	France
Clark, Walton, Jr., Capt.	Field Artillery	France
Coates, Jesse, Major	American Expeditionary Force	France
Cope, Thomas D., Captain	Air Service, U .S. A.	Langley Field
Cornelius, John C., 1st Lieut.	Coast Artillery, U.S.N.A., 13th Company	Sandy Hook
Cottrell, Jas. W., Sergeant	Instructor Ordnance Motor Instruction School	Metuchen, N. J.
Cowan, Henry B., Sergeant, 1st Class	Co. D., First Telegraph Battalion, Signal Reserve Corps	France
Crampton, George S., Major	Director of Field Hospitals, 28th Div., A.E.F.	France
Cushman, A. S., Lieut. Col.	Ordnance Dept., U.S.N.A.	Frankford Arsenal
Detwiler, Jas. G., 1st Lieut.	Infantry, U.S.R.	Fort Logan H. Roots
Douredoure, Bernard L.	Signal Service Officers' Training Camp	Camp Meade

Name and rank	Branch of service	Location
Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Edwards, John R., Rear Admiral	Brown University	Providence, R.I.
Elliot, A. H.	Engineers Reserve Corps	Philadelphia
Elliott, Henry M., 1st Lieut.	Ordnance Dept., U.S.R.	Western Cartridge Co.
Emerson, Geo. H., Colonel	In charge of Russian Railway Service Corps	Japan
Felton, Samuel M.	U. S. Director-General of Railways in connection with Expeditionary Force	Chicago
Ferguson, Walter B., Sergeant	21st Co., 154th Depot Brigade	Camp Meade
Fraser, Persifor, Ensign	U.S.N.R.F.	League Island
Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
Gfrörer, A. H., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Gibbons, Joseph E., Private	Co. D., 103rd Engineers	France
Gilbreth, Frank B., Major	Engineers O. R. C.	Washington
Gillmor, R. E., Senior Lieut.	U. S. Navy	New York
Glendinning, Robt. E., Major	Aviation Section, Signal Corps	Overseas
Gomberg, M., Major	Ordnance Reserve Corps	Washington
Goodwin, Harold, Jr., Lieut.	Naval Reserve Force, office, Chief of Naval Operations	Washington
Gribbel, W. G., Major	Engineers	Camp Humphreys
Griest, Thos. S., 1st Lieut.	1st Telegraph Battalion, Signal Corps, U.S.A.	France
Hall, R. T., Rear Admiral	U. S. Navy, Inspector of Machinery	Cramps' Shipyard
Hammer, William J., Major	Inventions Section, War Plans Division, General Staff, War College	Washington
Hodges, Austin L., Capt.	Ordnance Dept., U.S.R., Experimental Officer on Artillery Ammunition	Frankford Arsenal
Howson, Richard, 2nd Lieut.	Field Artillery	Camp Zachary Taylor
Ives, H. E., Captain	Signal Corps, U.S.A.	Washington
Jackson, John Price, Major		France
Jones, Jonathan, Major	E.O.R.C., 23rd Engineers, A.E.F.	
Junkersfeld, P. Major	E. O. R. C.	Washington
Karrer, Enoch, Senior Master Engineer	488th Engineers	Washington
Kennedy, M. C., Colonel	Deputy Director General of Transportation	France
Kent, S. Leonard, Jr., 1st Lieut.	34th Engineers	France
Kingsbury, E. F., Captain	Air Service Dept. of Science and Research	Washington
LeBoutillier, H. W., Private	Unit No. 10, Pennsylvania Hospital	France
Lenher, Victor, Major	Chemical Warfare Service, N.A.	Madison, Wis.
Lichtenberg, Chester, 1st Lieut.	Engineer Reserve Corps, U.S.A.	Washington
Lippincott, Joseph Wharton, Yeoman, 1st class	U. S. Naval Reserves	Washington
Littleton, Wm. Richards	Assistant Paymaster, U. S. N.	Philadelphia
Longstreth, Chas., Lt. Commander	U.S.N.R.F.	New Castle, Del.
Lucke, Charles E., Lt. Commander	U.S. Navy Gas Engine School	New York City, New York
McCoy, John F.	Aviation Section, Signal Corps	Princeton
MacLean, Malcolm R., Major	154th Depot Brigade	Camp Meade

Name and rank	Branch of service	Location
McMeekin, C. W., Major	Army War College	Washington
Martin, Thos. S., 1st Lieut.	Erie Proving Ground	Pt. Clinton, O.
Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Casper W., Major	Medical Corps. Division of Food and Nutrition	Washington
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, R. B., Major	Chief Signal Officer, Base Section No. 3, A.E.F.	London
Parrish, T. R., Captain	Signal Corps	Washington
Pemberton, Henry R.	U. S. Naval Air Service	Key West, Fla.
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France
Sessler, Grover C.	Assistant Civil Engineer, U. S. N. R. F.	Philadelphia
Spackman, Henry S., Lieut. Col.	Engineers, U. S. A.	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase, Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Captain	U. S. Navy	Boston
Synnestvedt, Arthur	Development Battalion	Camp Greenleaf
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	
Toulmin, H. A., Lieut. Col.	Assistant Chief of Staff, Air Service, A. E. F.	France
Ulmer, Carl D., Private	Chemical Warfare Service, A.E.F.	France
Vogleson, J. A., Major	Sanitray Corps	Camp Jas. E. Johnston
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr., Sergeant	Co. E., 304th Engineers	Camp Meade
Wells, G. A., Captain	Ordnance Reserve Corps	Peoria, Ill.
Wetherill, W. C., Lieut.	U. S. N., R. F. C.	Philadelphia
Weyl, Charles N.,	U.S.N.R.F.	Philadelphia
Widdicombe, R. A., Major	C.Q.M., Chemical Plant No. 4	Saltville, Va.
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	France
Worrell, Howard Sellers, 2nd Lt.	Coast Artillery School	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Railway Artillery Reserves	France
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Akeley, Carl E.	Consulting Expert of Mechanical Devices, War Department	Washington
Anderson, Robt. J.	Aeronautical Mechanical Engineer on Metallography, Bureau of Aircraft Production	Pittsburgh, Pa.
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington

Name	Appointment	Location
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J.
Cooke, Morris L.	Chairman, Storage Committee of Munitions Board; Member on Staff, Emergency Fleet Corporation	Washington
Day, Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Gudeman, Edward	Emergency Fleet Corporation	Chicago
Henderson, George R.	State Advisory Engineer, Federal Fuel Administration for Pennsylvania	Philadelphia
Honaman, R. Karl	Associate Physicist, Bureau of Standards	Washington
Hornor H. A.	Electrical expert for Industrial Training, Emergency Fleet Corporation	Philadelphia
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago
Humphreys, Rich'd L.	Director of Building Materials, Building Materials Div., War Industries Board	Washington
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman)	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Keller, Harry F.	Assistant Director of Allied Bodies, Department of Public Safety of Penna.	Philadelphia
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross, General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Osborne, L. A.	Member, National War Labor Board	Washington
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
Picolet, L. E.	Civilian Personnel, Trench Warfare Section, Ordnance Office	Washington

Name	Appointment	Location
Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U .S. Food Administration	Norman, Oklahoma
Rautenstrauch, Walter	Committee of the National Research Council	New York
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penna.
Rittmann, Walter F.	Consulting Chemical Engineer, U. S. Bureau of Mines	Pittsburgh
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sauveur, Albert	Director of Research, Division of Metallurgy, Technical Air Service, A.E.F.	France
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Steinmetz, Joseph A.	Member National Research Council, Engineering Division	Washington
Stern, Max J.	Supervising Surgeon, Merchant Shipbuilding Corporation	Philadelphia
Swenson, Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Taggart, Walter T.	Consulting Chemist, Nitrate Division, Ordnance Department	Philadelphia
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.
Turnbull, William P.	Department of Labor	Washington
Wadleigh, Francis R.	Emergency Fleet Corporation	Philadelphia
Warwick, J. F.	Bethlehem Loading Co.	Mays Landing, N. J.
Wharton, Henry	Y. M. C. A.	France

Please send additional information and corrections to the Secretary.

REPORT OF THE PRESIDENT.

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1918.

To the Members of the Franklin Institute:

Your Board of Managers has instructed me to report to you upon the work of the Institute for the year ending September 30, 1918. This writing is the report.

Your Board is able to report that in spite of the difficulties occasioned by the continued absence of the Secretary, the Science and Arts Assistant and four members of the Board of Managers, two of them Committee Chairmen, these absences being due to the war, all of the customary work of the Institute was carried on through the year.

The Managers hope that you will read the attached committee reports in full, and that this reading will bring to you the conviction that this work intrusted to them by you has been faithfully performed. It is by reading

these committee reports that the members may obtain the greatest measure of knowledge of the affairs of the Institute.

The year's operating expenses of the Institute were considerably greater in some details than in previous years, but, as you may learn from the report of the Finance Committee, the financial condition of the Institute remains good.

There is nothing of moment that the Board can add to what has been said in previous reports in reference to the Building Fund, which now stands at $474,000, of which $245,000 is invested in the building site on Logan Square.

The opening of the new Parkway makes more evident the great value for the purposes of the Institute of the property we now own on Logan Square at and near the corner of Nineteenth and Race Streets. During the past year we have acquired one new building and lot on this site, so that the Institute now owns five buildings and lots fronting on Race Street and four fronting on Nineteenth Street in the rear of these five.

The Board is still confident that the knowledge of the work the Institute is doing—work of great value to the citizen and to the State—will ultimately attract the funds necessary to the provision of a building more conveniently located and more nearly adequate to the accomplishment of the Institute's purposes than is this old and beautiful structure.

The work of the year is set out in detail in the reports of the committees, attached hereto, and to be printed in full in the 1918 Year Book. I comment briefly upon these reports as follows:

The Library Committee, Doctor Leffman, chairman, reports 2388 additions to the Library. Other interesting information is contained in the report, including some reference to the difficulties of operation during the period of war.

The Committee on Museums, Mr. Outerbridge, chairman, reports a number of valuable additions to the group of models and historical apparatus.

The report of the Committee on Meetings, Doctor Alleman, chairman, is mainly a record of the stated meetings of the Institute held, the subjects discussed and the medals awarded. Members who read this report will have an appreciative knowledge of the importance of the lecture course.

The report of the Committee on Stocks and Finance, Mr. Forstall, chairman, contains a list of the funds held by the Institute and a statement of the receipts and expenditures of the year. I quote the last paragraph of this report in its entirety and express the hope that the members will read the report in full.

"The total increase since last year in the principal of all funds amounts to $14,040.91, of which the principal item is $12,778.97 for the Franklin Institute Building Fund. It is a gratifying fact that under war conditions we were able to close the year with a surplus in operating account of $539.38."

During the months of difficulty through which we recently have passed, reassuring, indeed, has been the knowledge that the securities owned by the Institute and in the custody of its Board of Trustees, Mr. Fraley, chairman, are in the main of the highest reliability and reasonably certain to retain their earning value. Your Board feels little anxiety about them, though there has been some shrinkage in their market value.

The report of the Committee on Sectional Arrangements, Doctor Keller, chairman, contains a statement of the meetings of the Sections, with their

many important lectures and discussions. It is interesting to note that during the year joint meetings have been held with the American Society of Electrical Engineers, the Illuminating Engineering Society and the Physics Club.

The report of the Committee on Publications, Mr. Levy, chairman, in addition to the detail usual to the Annual Report of the Committee, calls attention to a reduction of 16 pages in the size of the JOURNAL, made pursuant to the request of the government for a conservation of paper. A large increase in the cost per page of printing the JOURNAL made this step important for reasons of economy in expenditure of the funds of the Institute, as well as in the stock of paper.

The report of the Committee on Instruction, Mr. Paul, chairman, contains a statement of the work undertaken at the government's request in the field of wireless transmission of intelligence, as well as the general detail of the usual work of the schools.

The report of the Committee on Science and the Arts, Doctor Creighton, chairman, is mainly a statement of the activities of the Committee during the year. It shows that the standards of the Committee were well maintained. Thirty-nine subjects were considered and twenty-one awards made.

The Committee on Exhibitions, Mr. Chambers, chairman, reports no activities during the year.

The Committee on Election and Resignation of Members, Mr. Gibbs, chairman, reports the election of—

Resident members	15	
Non-resident members	17	
Associate members	7	
Life members	5	
Second class stock members	1	
Total		45

The resignation of—

Resident members	16	
Non-resident members	13	
Associate members	1	
Total		30

The deaths of—

Resident members	5	
Non-resident members	7	
Life members	5	
Total		17
Total of resignations and deaths	47	
Dropped for non-payment of dues	10	
		57
Losses in membership—all classes		12

In this connection your Board of last year reported to you as follows:

"Our membership grows slowly. We are not very good advertisers, and knowledge of the value of the Institute's work is not forced upon the community. We do not conduct campaigns for membership or for funds. Doubtless we will attract a larger membership when we are domiciled in a more prominent and popular location."

During the two years just past, many of the members of the Institute, those of them suitably aged and conditioned, have been absent from our councils in the active service of their country—a service of honor and of danger. And we have missed them. Those of us not so happily aged and conditioned have endeavored in our less heroic sphere to maintain the traditional work of the Institute, and, where opportunity has offered, to turn the energies of our organization to the furtherance of the great cause. The committee reports of the two years last past indicate the measure of success attained.

Fellow members of The Franklin Institute, important as is the service we and kindred institutions are created to render, there is another class of service not mentioned in our charter and, at the moment, more important to the world than the promotion of the mechanic arts, or aught else, and to the consideration of this and of our relation to it, with the approval of your Board of Managers, I devote a few sentences.

The great war, now happily ended, has had a profound influence on all the political and social relations of the civilized world. Even in our own country of free institutions and of equality of opportunity, the ferment of unrest—the thirst for change, sometimes, illogically, for the change's sake only—is present, as is also the impulse, often as illogical, to resist all or any change. With affairs political and affairs social we, as an institution, have nothing to do. In our democratic body, in the membership of The Franklin Institute, are men of many creeds and of many political convictions. As a body we have no political bias—we have no social formulæ. We rejoice that this is so. And we, members of The Franklin Institute, a democratic organization for the promotion of the scientific interests of the state and the citizen, may reasonably believe, and believing rejoice, that our institution, pursuing amid the political and social ferment of the time the even tenor of its way, one hundred years old, yet ever young, bearing a century of tradition, yet in step with the most modern thought, that this institution, composed of men of widely different social and political creeds, offers a compelling example in conservatism to the radical and in progress to the Bourbon. While we disclaim any function other than the promotion of the mechanic arts, we are a stabilizing influence on the political and social life of the community. This by-product of the Institute's efforts to be useful, though having nothing to do with its declared purposes, though not the result of any conscious effort, is none the less real, none the less valuable to the community. The realization of its existence should be an highly gratifying thought and a stimulating influence to each of us. This is the thought that came to me as I strove to apprehend the influence of the great world upheaval upon the Institute and of the reaction of the Institute upon it.

We enter the New Year—we face the problems of the new year confident that in the days to come as in the years past there will be opportunity for

such useful work as the Institution is equipped to execute; and the members of your Board of Managers looking forward to this continuing opportunity are appreciative of the privilege and responsibility of the position of control to which you have chosen them.

Respectfully submitted,

The Board of Managers,
WALTON CLARK,
President.

PHILADELPHIA, January 15, 1919.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, January 8, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 8, 1919.

DR. H. JERMAIN CREIGHTON *in the Chair.*

The following report was presented for final action:

No. 2727: Stabilized-Platform Weighing Scale. Final action deferred.

The following report was presented for reconsideration:

No. 2708: Waterbury Hydraulic Speed Gear. Report referred back to Sub-Committee for a recommendation.

GEO. A. HOADLEY,
Acting Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, January 9, 1919, at 8 o'clock, with Mr. Walton Forstall in the chair. The minutes of the previous meeting were approved as read.

M. Luckiesh, Chairman of the Committee on Camouflage of the National Research Council, delivered an illustrated address on "The Principles of Camouflage for Land, Sea and Air." The underlying principles, the evolution of camouflage from a science to an art, and its practice were described. Factors governing the visibility of airplanes were discussed.

On motion of Lieut. W. C. Wetherill, a vote of thanks was extended to Mr. Luckiesh. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, January 8, 1919.)

RESIDENT.

MR. SAMUEL S. SADTLER, Consulting Chemist, 210 South Thirteenth Street, Philadelphia, Pennsylvania.

DR. THEODORE B. SCHNEIDEMAN, Oculist, 1831 Chestnut Street, Philadelphia, Pennsylvania.

CHANGES OF ADDRESS.

LIEUTENANT COMMANDER A. W. K. BILLINGS, Apartado 491, Barcelona, Spain.
MR. STERLING H. BUNNEL, 6 Hanover Street, New York City, New York.
PROFESSOR JOSEPH A. CORCORAN, 8 36th Avenue, Lachine, P. Q., Canada.
MAJOR GEORGE S. CRAMPTON, Director of Field Hospitals, Headquarters, 103 Sanitary Train, 28th Division, A. E. F., France.
MR. THOMAS DUNCAN, in care of Burlington Apartments, 9th Street and Burlington Avenue, Los Angeles, California.
LIEUTENANT R. E. GILLMOR, in care of Sperry Gyroscope Company, Manhattan Bridge Plaza, Brooklyn, New York.
MR. FRANCIS H. GILPIN, in care of Texas Company, Asphalt Department, 17 Battery Place, New York City, New York.
MR. F. G. GRIMSHAW, Assistant to General Manager, Pennsylvania Railroad Company, Eastern Lines, 724 Commercial Trust Building, 15th and Market Streets, Philadelphia, Pennsylvania.
MR. R. A. MARRIOTT, 213 Hickory Street, Anaconda, Montana.
MR. FREDERICK W. SALMON, 521 North 20th Street, Birmingham, Alabama.
MR. WILSON E. SYMONS, in care of Galena Signal Oil Company, 17 Battery Place, New York City, New York.

NECROLOGY.

William L. DuBois, a member of The Franklin Institute since 1866 and of its Board of Managers from 1880 to 1882, died at his home in Philadelphia on October 26, 1918, just at the close of his seventy-fourth year, he having been born in this City October 27, 1844. His active life was spent in the service of the Philadelphia Trust Company, of which he was President for many years before his retirement in 1910, remaining thereafter Chairman of its Board of Directors until his death.

Mr. DuBois was a son of William Ewing DuBois, long Assayer of the United States Mint, and the descendant of a noted Huguenot refugee, Louis DuBois, of New Paltz, New York. He is survived by his widow, Mary Cowell, and by his son, Captain Henry C. DuBois, who is stationed in Washington.

Isaac Norris, M.D., one of the very oldest members of The Franklin Institute, died October 22, 1918, after a short illness in Florence, Italy, where he had resided for some years past. Doctor Norris was in his eighty-fifth year, having been born in Philadelphia, June 12, 1834. He was a member of one of the historic families of Philadelphia, a granduncle and namesake of his having been one of the signers of the Declaration of Independence. He was graduated from the University of Pennsylvania in the class of 1852, and three years later obtained the degree of Doctor of Medicine. He served as Acting Assistant Surgeon of the Nicetown Hospital during the Civil War, and thereafter for two years as Physician of the Philadelphia Dispensary, being at the same time active as Professor of Chemistry of Central High School in Philadelphia.

Doctor Norris joined The Franklin Institute in 1866 and up to recent years,

when his frequent journeys abroad eventuated in his taking up his residence in Florence, he took an active and prominent part in its affairs. He was a member of the Board of Managers from 1870 to 1878, then Secretary of the Institute from 1879 to 1881, and again a member of the Board from 1883 to 1918.

He evinced his interest in the general field of science by his active membership in various other societies. He was a member of the American Philosophical Society, Academy of Natural Sciences and the Historical Society of Pennsylvania, of various medical societies and a fellow of the Philadelphia College of Physicians and Surgeons and one of its Secretaries. He took a leading part in the movement for the establishment of a Free Public Library in Philadelphia, and the start of the present great institute was largely due to his efforts. His private library, now in the home of his son at Bryn Mawr, was collected by him in the course of his manifold activities and is a monument to his zeal as a booklover.

Doctor Norris married in 1862 Clara Lamb, and is survived by a son and daughter, Isaac and Clara Norris.

Mr. Walter V. Turner, Wilmerding, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

BONE, W. A.—Coal and Its Scientific Uses. 1918.

BREARLEY, A. W., and H.—Ingots and Ingot Moulds. 1918.

CROSBY, E. U., FISKE, H. A., and FOSTER, H. W.—Handbook of Fire Protection. 1919.

FERRY, E. S.—Handbook of Physics Measurements. 1918.

HALE, A. J.—Applications of Electrolysis in Chemical Industry. 1918.

HOFMAN, H. O.—Metallurgy of Lead. 1918.

JACOBY, H. S.—Structural Details, or, Elements of Design in Timber Framing. 1918.

TILDEN, SIR W. A.—Sir William Ramsay, Memorials of His Life and Work. 1918.

WALTON, ERICH.—Manual for the Essence Industry. 1916.

WATSON, E. R.—Colour in Relation to Chemical Constitution. 1918.

WEGMANN, EDWARD.—Conveyance and Distribution of Water for Water Supply. 1918.

PUBLICATIONS RECEIVED.

A Handbook of Physics Measurements, by Ervin S. Ferry, in collaboration with O. W. Silvey, G. W. Sherman, Jr., and D. C. Duncan. Vol. i, Fundamental Measurements, Properties of Matter and Optics. Vol ii, Vibratory Motion, Sound, Heat, Electricity and Magnetism. First edition, 2 vols., illustrations, 8vo. New York, John Wiley and Sons, Inc., 1918. Price, $4.00.

Topographic Stadia Surveying: A manual with reduction tables and a new type of reduction diagram, by C. E. Grunsky, Eng. D. 99 pages, illustrations, plates, 16mo. New York, D. Van Nostrand Company, 1917. Price, $2.00.

The Science of Fruit Growing Based on Nature's Laws, by Virgil Bogue. 83 pages, portrait, 24mo. Rochester, N. Y., Democrat and Chronicle Print, 1917. Price, $2.00.

U. S. Department of Agriculture: Bulletin 724. Professional paper. Drainage Methods and Foundations for Country Roads, by E. W. James, General Inspector; Vernon M. Peirce, Assistant Engineer; Charles H. Moorefield, Senior Highway Engineer. 86 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1918.

Canada Department of Mines: Summary report of the Mines Branch for the calendar year ending December 31, 1917. 153 pages, illustrations, map, 8vo. Ottawa, King's Printer, 1918. Price, 15 cents.

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CURRENT TOPICS.

The Self-loading Military Rifle. E. C. CROSSMAN. (*Scientific American*, vol. 119, No. 14, p. 272, October 5, 1918).—Every civilized nation has experimented with military rifles of the self-loading type. No rifle in pre-war days fulfilled all the necessary requirements in point of simplicity, endurance and reliability. Now, the demands on the rifle in the way of ease of cleaning and care, and immunity to abuse, mud and grit, are greater than in the days before the war, and the satisfactory rifle to fill the need seems farther away than ever. Rifles that do the work of breech manipulation are roughly divided into two classes—recoil-operated and gas-operated. Machine guns follow the same classification, and are about evenly divided in actual number now in operation. The Maxim, which is the standard German machine gun, is recoil-operated. The Benet-Mercier, the Lewis, and the Colt are gas-operated.

The sporting rifles sold to hunters are confined strictly to the recoil-operated type, represented by the Remington, the Winchester and the little known Sjogren of England. The designer of the recoil-operated, self-loading rifle—often miscalled "automatic"—is confronted with the difficult task of both locking his rifle firmly against the thrust of the cartridge, and yet utilizing that impulse to operate the mechanism. If it is permitted merely to oppose a heavy unlocked bolt and a powerful spring to the backward push of the cartridge, then the task is easy, and we get what is called the "blow-back" type of weapon, a type including the familiar and successful Winchester self-loading rifles and various automatic pistols. In that type there exists a necessarily delicate balance between backward thrust of the cartridge case, mass of the bolt and push of the retractor spring behind it.

If the bolt and spring offer inadequate resistance, then the speed of the recoiling parts will be too great and there will be an escape of powder gas at the breech, and probably rupturing the cartridge case because the back portion would be pushed out under the gas pressure, while the forward and thinner part remains tightly held in frictional contact with the chamber walls by the same powder pressure. If the bolt and spring offer too much resistance, then the breech mechanism will merely not function. Any overload or serious obstruction in the bore, tending to raise the chamber pressure, would destroy this balance, and so the refusal of the military boards to countenance this type of action. It, however, operates satisfactorily in sporting arms.

While necessitating a clumsy barrel cover, the Browning plan of recoil-operated rifle is thus far the most practical and one much copied in foreign rifles of the military automatic type. In the Brown-

ing plan, used in the big-game series of self-loaders, the recoil drives backward the breech-bolt and barrel firmly locked together, the barrel sliding in guides provided therefor. The backward motion compresses the retractor and mainsprings. At the end of the travel, which is about the length of a cartridge, a trip releases the lock between bolt and barrel, the heavy retractor spring drives the barrel forward to position again, ejecting the fired case, while the breech bolt is momentarily held back. A fresh cartridge rises into the path of the bolt, which then flies forward, carrying the cartridge into the chamber, and locks itself by the turning of the bolt head under locking shoulders, as with the Mauser hand-operated rifle. The Browning plan is used on the Danish Schoeboe rifle submitted in military form to our War Department in 1909. The same plan is embodied in the Swedish Kjellman rifle submitted in 1910.

A third application of the recoil principle is the forward-moving barrel idea seen in the Swartzlose automatic pistol sold in this country prior to the war. Here the "drag" against the light barrel is alleged to force the barrel forward to the limit of its travel. As a matter of fact the in-part backs away from the barrel, much as the Sjogren rifle backs away from the sliding locking bolt. This is proved by the fact that if the firing hand is placed against a wall and the trigger pulled, the arm will not function; the backward jump of the pistol has really more to do with the functioning of the arm than the actual forward motion of the barrel.

All devices depending on recoil, however, are more or less clumsy and complicated compared to the simple plan of taking a little gas from the barrel and using it to operate a miniature piston in a cylinder below the barrel. This is the operating principle of the Benet-Mercier and Lewis machine guns. The Colt uses gas, but lets it impinge on the lever hinged below the barrel. The small portion of gas used has no effect on the ballistics of the arm. Such gas operation permits the use of the simple and strong bolt of military type. It is quite safe in that the operation of the bolt cannot commence until the bullet passes the port near the muzzle and has only a short distance to travel before exit. The objections to gas operation are the slight tendency of the working parts to corrode from the gas and the slightly greater difficulty in keeping the bore clean, due to the creeping up of erosion from the unreachable gas-port in the barrel. Care can prevent this trouble.

(It is of interest to note that the retractor spring in a recoil-operated weapon has no appreciable effect in opposing the backward push of the cartridge; its sole function is to push a fresh cartridge into the barrel and to hold the breech bolt in place, and substantially the whole effect is due to inertia. This point was demonstrated with an early model 32-calibre Colt automatic pistol of the "blow-back" type. The retractor spring was removed and the pistol was fired, pointing downward to keep the bolt in contact with the cartridge. The arm functioned properly, except that the breech remained open.—ED.).

Lead Plating. ANON. (*Brass World*, vol. 14, No. 11, p. 321, November, 1918.)—According to a circular issued by the Bureau of Standards in collaboration with the Army Ordnance Department, lead plating is conducted similarly to any other plating operation, and can be readily installed and operated wherever there are plating facilities and an experienced plater. Wooden tanks, preferably lined with asphalt or bitumen, are suitable for the purpose; iron or lead linings should not be used. The solutions after mixing are not especially corrosive, and are not so poisonous as many other plating solutions in common use. Danger of lead poisoning may be avoided by the use of the customary precautions. Briefly, the operation of lead plating consists in hanging the properly cleansed articles in the plating solution upon the cathode rods and lead plates or sheets of suitable size upon the anode rods.

The only two solutions in extensive commercial use are the fluosilicate and fluoborate solutions. The former is made by dissolving lead carbonate in fluosilicic acid, which in turn is prepared by the action of hydrofluoric acid on silica. As the preparation of the fluosilicate solution is a rather complicated process, it is customary for the platers to purchase this solution from the refineries in which it is used on a large scale for the refining of lead. Observation has shown that most of the platers using fluosilicate solutions make further additions to the solutions as purchased, such as glue, molasses, oxalic acid, etc. The fluoborate solution is prepared by dissolving boric acid in hydrofluoric acid, and then adding the lead carbonate (in the form of a paste), and the requisite amount of glue, after which the solution is diluted to the desired volume or density. Dense, satisfactory deposits of lead can be produced in either the fluosilicate or fluoborate solution, but it is believed that for new installations the fluoborate solution will be most satisfactory. The fluoborate solution may be used to plate directly on steel, whereas in the fluosilicate solution the steel must first be copper-plated or receive other special treatment.

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